BROOKS CREEK
DIAGNOSTIC STUDY
Jay County, Indiana

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BROOKS CREEK WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

Brooks Creek and its tributaries drain almost 43 square miles (27,440 ac; 11,109 ha) of Jay County into the Salamonie River west of Portland, Indiana. The creek and its tributaries originate in the Mississinewa Moraine left behind by the Wisconsian Glacial Period 21,000 years ago. The soils are predominantly fine silts and clays that are highly erodible and severely limited for septic tank absorption fields. The original vegetation was primarily beech-maple forest. Only about 8% of the watershed still remains forested. Approximately 89% of the watershed land use is agriculture, including 76% row cropping, with the remainder in pasture or hay. Much of the land is considered prime farmland due to the high nutrient content and available moisture in the clay soils.

Conservation tillage practices are used on approximately 15-20% of the land in corn production and up to 90% of the fields planted to soybeans. This figure suggests that producers are using no-till or minimum till for soybeans and then rotating to corn and using partial or full till. The majority of benefits from no-till are derived after three years and are minimized by rotating in and out of other tillage practices. Nutrient management techniques are under utilized in Jay County and could be improved with more frequent soil testing, spot fertilization, and better consideration of legume nitrogen fixation and conservation tillage practices. Conservation tillage and better nutrient management will improve water quality by allowing less nutrients to leach to the waterway.

While no endangered, rare, or threatened species remain in the Brooks Creek watershed, invertebrate and fish communities are severely limited due to the sediment loading and constant alterations of the habitat by ditch cleaning. The macroinvertebrate Index of Biotic Integrity (mIBI), an index which utilizes invertebrate community structure to measure water quality, documented a range of severely impacted (0) to just barely unimpaired (6.0). Water quality samples taken during storm events exceeded state standards for various chemical parameters and for *E. coli* at many sample sites.

The Brooks Creek watershed was divided into smaller subwatersheds in order to prioritize the greatest needs for Best Management Practices (BMPs). The Crooked Creek Subwatershed has the greatest need for BMP implementation followed by the Smith-Hartman Ditch Subwatershed. Additional work recommended in the watershed included fencing of livestock from streams, working with the County Health Department to decrease pollution from private wastewater systems, filtration of storm water runoff from roads and bridges, grade and bank stabilization of the streams where recommended, and water retention in the headwater areas.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources – Division of Soil Conservation and the Jay County Soil and Water Conservation District. J.F. New and Associates, Inc. and Indiana University – School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Significant contributors to this study included Brian Wurm of the Wells County Soil and Water Conservation District and Dennis Chenoweth and Michelle Miller of the Jay County Soil and Water Conservation District. A special thank you is due Doug Nusbaum for his initiative and assistance in getting this study completed. Jill Hoffmann, Ed Braun, Brant Fisher, and numerous others assisted with their comments and contributions on historic watershed activities. Authors of this report include William Jones, Melissa Clark, and Joel Klumpp at Indiana University and Cornelia Sawatzky, Marianne Giolitto, John Richardson, and Steve Zimmerman at J.F. New and Associates, Inc.

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JAY COUNTY, INDIANA

INTRODUCTION

The Brooks Creek Watershed is located southwest of Portland in Jay and Blackford Counties, Indiana and drains about 27,440 acres (Figure 1). The Brooks Creek Watershed encompasses two 14-digit watersheds, the Brooks Creek-Mud Creek Watershed (HUC 05120102020200) and the Brooks Creek-Cowboy Run Watershed (HUC 05120102010090). The watershed is part of the 11-digit watershed HUC 05120102010 and the 8-digit watershed HUC 05120102. The study area lies within Knox, Green, Jefferson, and Richland Townships. For the purpose of this study, the watershed was further divided into twelve smaller subwatersheds (Figure 2).

Water from Brooks Creek discharges into the Salamonie River directly south of Pennville. The Salamonie River flows northwest where it joins the Wabash River, which eventually reaches the Ohio River in southwestern Indiana. It is important to note that all the study streams are legal drains. Legal drains are important for necessary water conductance to sustain a variety of land uses, including agriculture. Disturbance to the system is inevitable due to periodic drainage improvement projects. Additionally, projects constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted should they impede drainage.

The drainage basin of Brooks Creek was formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Ontario-Erie Lobe of the last Wisconsian glaciation and the deposits left by the lobe shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). In Jay County, the receding glacier left nearly level topography overlain by morainal deposits of high clay content.

The study watershed is located in the east-central portion of the Central (Bluffton) Till Plain Natural Region (Homoya et al., 1985). The Central Till Plain is the largest natural region in Indiana and includes most of the central part of the state. Prior to European settlement, the region was a beech-maple-oak forested plain, accompanied by small bog, prairie, fen, marsh, and lake areas (Homoya et al., 1985). The poorly-drained flatwoods were likely forested with red maple, pin oak, bur oak, swamp white oak, Shumard's oak, American elm, swamp cottonwood, and green ash. Slightly better-drained soils probably harbored beech, sugar maple, black maple, white oak, red oak, shagbark hickory, tulip poplar, red elm, basswood, and white ash. The first plat of Indiana by the General Land Surveyors documented beech-maple forests as comprising 50% or more of the original vegetation of the state (Petty and Jackson, 1966).

Changes in land use have altered the watershed's natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George

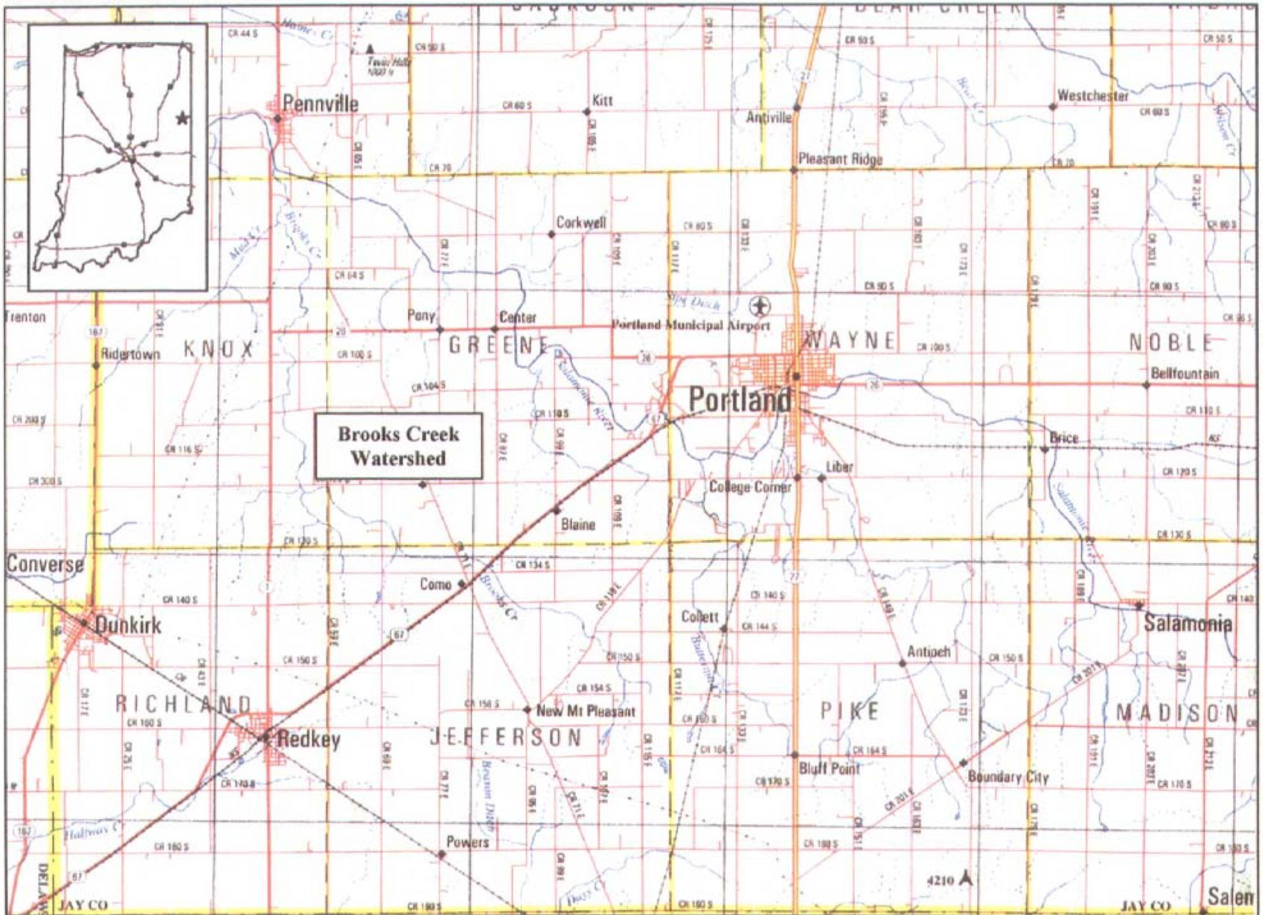

FIGURE 1. Location map of the diagnostic study watershed in Jay County, Indiana.

Scale: 1" = 2.5 miles

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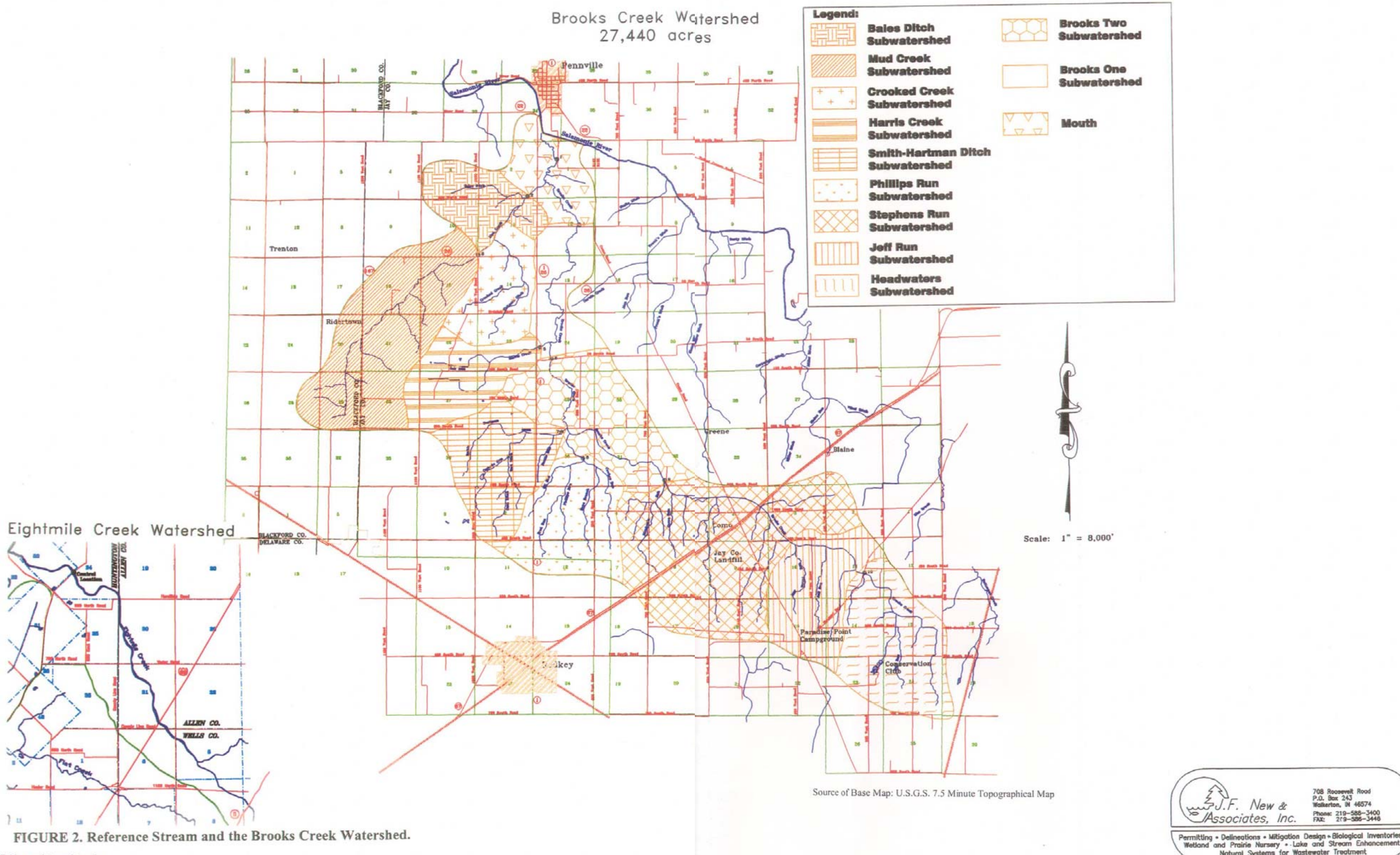


FIGURE 2. Reference Stream and the Brooks Creek Watershed.

Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately 89% of the watershed is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has resulted in conversion of prairies and wetlands to agriculture. The effect of these drainage activities on water quality has been negative, resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Menzel (1983) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Brooks Creek Watershed. However, Indiana Department of Environmental Management 305(b) reports from 1989 to the present have indicated non- or only partial support of beneficial uses at sampling sites on the Salamonie River near the towns of Portland and Lancaster. Evidently, human impacts within this area of the Salamonie River watershed are having an adverse effect on water quality and beneficial uses.

Because there is little information about this watershed and in order to gain a better understanding of it, the Jay County Soil and Water Conservation District applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a watershed diagnostic study. The purpose of this study is to describe the conditions in the watershed, identify potential problems, and make prioritized recommendations addressing these problems. This study includes a review of historical data and information, correspondence with landowners, business owners, and state and local regulatory agencies, collection of stream water quality samples and benthic macroinvertebrates, and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

REVIEW OF EXISTING INFORMATION

Watershed Physical Characteristics and Geology

The Brooks Creek Watershed totals 27,440 acres (11,109 ha or 43 square miles). Tables 1 and 2 contain overview data for the watershed including subwatershed area and stream lengths for all named streams. The landscape can be described as a relatively flat till plain, known as the Tipton Till Plain in physiographic terms. Brooks Creek drains directly into the Salamonie River, a tributary to the Wabash River. The Wabash River eventually reaches the Ohio River in southwestern Indiana and drains water from about two-thirds of the state (Hale, 1966).

TABLE 1. Watershed area for the twelve Brooks Creek subwatersheds and for the Brooks Creek Watershed as a whole.

Watershed/Subwatershed	Watershed Area
Bales Ditch Subwatershed	1,318 acres (534 ha)
Mud Creek Subwatershed	3,718 acres (1,505 ha)
Crooked Creek Subwatershed	1,433 acres (580 ha)
Harris Creek Subwatershed	1,643 acres (665 ha)
Smith-Hartman Ditch Subwatershed	2,185 acres (885 ha)
Phillips Run Subwatershed	2,106 acres (853 ha)
Stephens Run Subwatershed	5,072 acres (2,053 ha)
Jeff Run Subwatershed	2,063 acres (835 ha)
Headwaters Area Subwatershed	2,540 acres (1,028 ha)
Mouth	1,234 acres (500 ha)
Brooks One Subwatershed	2,668 acres (1,080 ha)
Brooks Two Subwatershed	1,345 acres (545 ha)
Brooks Creek Watershed Total	**27,440 acres (11,109 ha)**

TABLE 2. Stream length of all named streams and length of the entire Brooks Creek system.

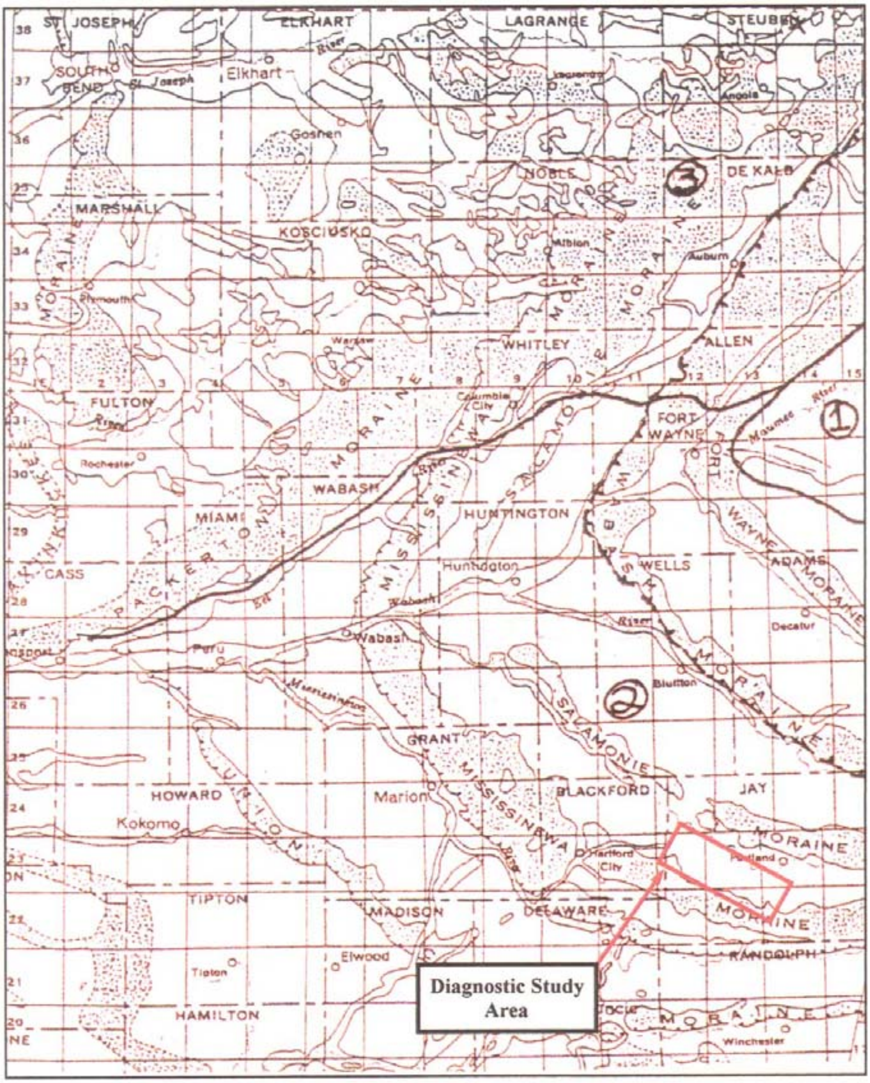
Creek/Ditch	Stream Length (miles)	Stream Length (km)
Bales Ditch	1.8	2.9
Mud Creek	12.1	19.5
Crooked Creek	1.4	2.2
Whitaker Ditch	2.8	4.5
Harris Creek	2.8	4.5
Oak Run	1.2	1.9
Smith-Hartman Ditch	2.6	4.3
Carrode Run	1.4	2.3
Rust Ditch	3.2	5.1
Rustic Run	0.9	1.5
Bit Run	1.3	2.1
Boot Run	1.4	2.2
Phillips Run	2.1	3.4
Rope Branch	1.7	2.7
Cowboy Run	2.6	4.2

Stephens Run	4.3	6.9
Como Run	1.2	1.9
New Mount Run	1.8	2.9
Jeff Run	1.7	2.7
Bost Run	1.3	2.1
Brooks Creek Mainstem	17.6	28.4
Brooks Creek System Total	**83.1**	**133.7**

The Brooks Creek Watershed drains part of the Mississinewa Moraine (Figure 3), a deposit left behind by the clay-rich, Ontario-Erie Lobe of the most recent Wisconsian glacier about 16,000 years ago. Prior to the Wisconsian Age, Indiana had been glaciated twice, though the Wisconsian glacier can be credited with building northeastern topography in Indiana. During the main advance about 21,000 years ago, the Wisconsian glacier covered two-thirds of the state. The glacier then advanced and retreated many additional times forming the topography of the state.

Figure 3 shows the terminal moraines deposited by the Erie Lobe at different times during the Wisconsian glaciation (Indiana University/Purdue University, Ft. Wayne, 1996). From the oldest to youngest they include: the Union City, Mississinewa, Salamonie, Wabash, and Fort Wayne Moraines. The Mississinewa and the Wabash Moraines are the largest, spanning up to several miles in width and standing 100 feet above adjacent plains. After the deposition of the Salamonie Moraine, the melting glacier retreated a large distance. The meltwater formed a greatly enlarged ancestral Lake Erie which produced very fine lacustrian mud and till. These are the modern day components of the Wabash Moraine. After depositing the most northern moraine (Fort Wayne Moraine), the glacier melted forming Lake Maumee. The overflow of the massive amounts of water contained in the glacier carved out a broad floodplain which is currently occupied by the Wabash River.

Distinct landforms and topography are evident in and adjacent to the Mississnewa Moraine and are associated with distinctive sediment types. The four morainal landforms associated with the study watershed include: the face, the toe, the till plain area, and the Salamonie River Valley. The face is the steep, northeast-facing slope of the moraine. The headwaters of small tributaries to Brooks Creek begin on the face terrain. The topography associated with the face area is relatively steep. The toe lies a bit further northeast immediately in front of the face and is very gently sloping. Upper reaches of Brooks Creek itself and some of the larger, lower reaches of its tributaries drain water from the toe area. The till plain or washed area borders the toe to the north. This area is associated with the larger, lower sections of streams that have their origins higher on the face or toe of the moraine. Of highly dissected topography, this feature represents former meltwater channels that carried water away from the melting glacier. The lower section of Brooks Creek lies within the till plain area as it flows north to the Salamonie River. The Salamonie River was the principle channel carrying meltwater from the ice front when the moraine was formed (IU/Purdue Ft. Wayne, 1996).



Source: Atlas of Mineral Resources of Indiana, Map No. 10

Figure 3. Moraine deposits in Northern Indiana from the Wisconsian Glacial Period during the Pleistocene Period

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Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds are generally from the southwest, but are more persistent and blow from a northerly direction during the winter months. Flooding is common in Indiana and occurs in some part of the state almost every year. The months of greatest flooding frequency are December through April. Causes of flooding vary from prolonged periods of heavy rain to precipitation falling on snow and frozen ground.

Jay County Climate

The climate of Jay County is cold in the winter but quite hot in the summer. Winters average 28ºF (-2ºC), while summers are warm, averaging 72ºF (22ºC). The highest temperature ever recorded was 101ºF (38ºC) on September 2, 1953. Mild drought conditions occur occasionally during the summer when evaporation is highest. Yearly annual rainfall averages 36.4 inches (93 cm), while winter snowfall averages about 29 inches (84 cm). During summers, relative humidity varies from about 60 percent in midafternoon to near 80 percent at dawn. The growing season typically begins in early April and ends in mid-October.

In 2000, almost 37 inches (94 cm) of precipitation (Table 3) was recorded at Portland in Jay County (http://shadow.agry.purdue.edu/sc.index.html). This amount exceeded that received during 1999, which was widely recognized as a drought year. During 1999, only about 25 inches of rain fell at the rain gage site in Portland. When compared to the 30-year average rainfall for Jay County, 2000 was almost exactly average. Even though the difference between the annual total precipitation in 2000 compared to the annual average is very similar, the year was characterized by significant wetter-than-normal and drier-than-normal periods. During 2000, the early spring and late fall periods were drier than normal, while the area received more rain than normal in June and September.

TABLE 3. Monthly rainfall data (in inches) for year 2000 as compared to average monthly rainfall. Averages are based on available weather observations taken during the years of 1961-1990 (http://shadow.agry.purdue.edu/sc.index.html).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2000	1.53	2.03	1.64	3.64	4.28	5.35	4.08	3.66	5.31	1.59	1.28	2.29	36.68
Average	1.91	1.95	3.02	3.70	3.72	3.84	4.00	3.65	2.96	2.51	2.93	2.71	36.9

Soils

Introduction

The soil types found in Jay and Blackford Counties are a product of the original parent materials deposited by the glaciers that covered the area 12,000 to 15,000 years ago. The main parent materials found in these two counties are glacial outwash and till, lacustrine material, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in Jay and Blackford Counties today. Surficial Erie Lobe deposits are extremely fine-grained silty clay to silty-clay loams within and east of the Mississinewa moraine, the morainal structure drained by the watershed (Figure 3). In fact, incorporation of ancestral Lake Erie mud led to the deposition of till that is commonly about 90% silt and clay (Fleming, in prep.).

The USDA soil survey of Blackford and Jay Counties (Kluess, 1986) maps the watersheds in soil types derived from glacial till parent materials. Lighter colored soils developed under forests, and darker colored soils represent former marshland soils (Ulrich, 1966). The drainages of Brooks Creek are composed primarily of Blount-Pewamo-Glynwood, Glynwood-Blount-Pewamo, and Glynwood Associations. The first two of these soil associations are nearly level to moderately and are poorly drained to moderately drained silty, clayey, and loamy soils. Glynwood Associations are found in sloping areas and are loamy, moderately well drained soils. The bedrock underlying the surficial soil associations in the counties is composed of limestone, shale, and sandstone.

Highly Erodible Soils

Soils in the watersheds and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems with which they converge. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they impair water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Figure 4 maps the presence of highly erodible soils in the study watersheds. It is important to note that this map is based on the Natural Resource Conservation Service (NRCS) criteria for highly erodible soils and is not field checked. Soil unit names considered highly erodible by the NRCS are included in Table 4. Nine thousand six hundred nineteen acres (3,892 ha) of land (almost 38% of the watershed) are mapped as highly erodible soil. The Headwaters Area and Jeff Run Area Subwatersheds contain the most highly erodible soils as a percentage of total land area, while soils lower in the watershed generally contain less highly erodible soil area. The Bales Ditch and Harris Creek Subwatersheds contain the least amount of soil types mapped as highly erodible.

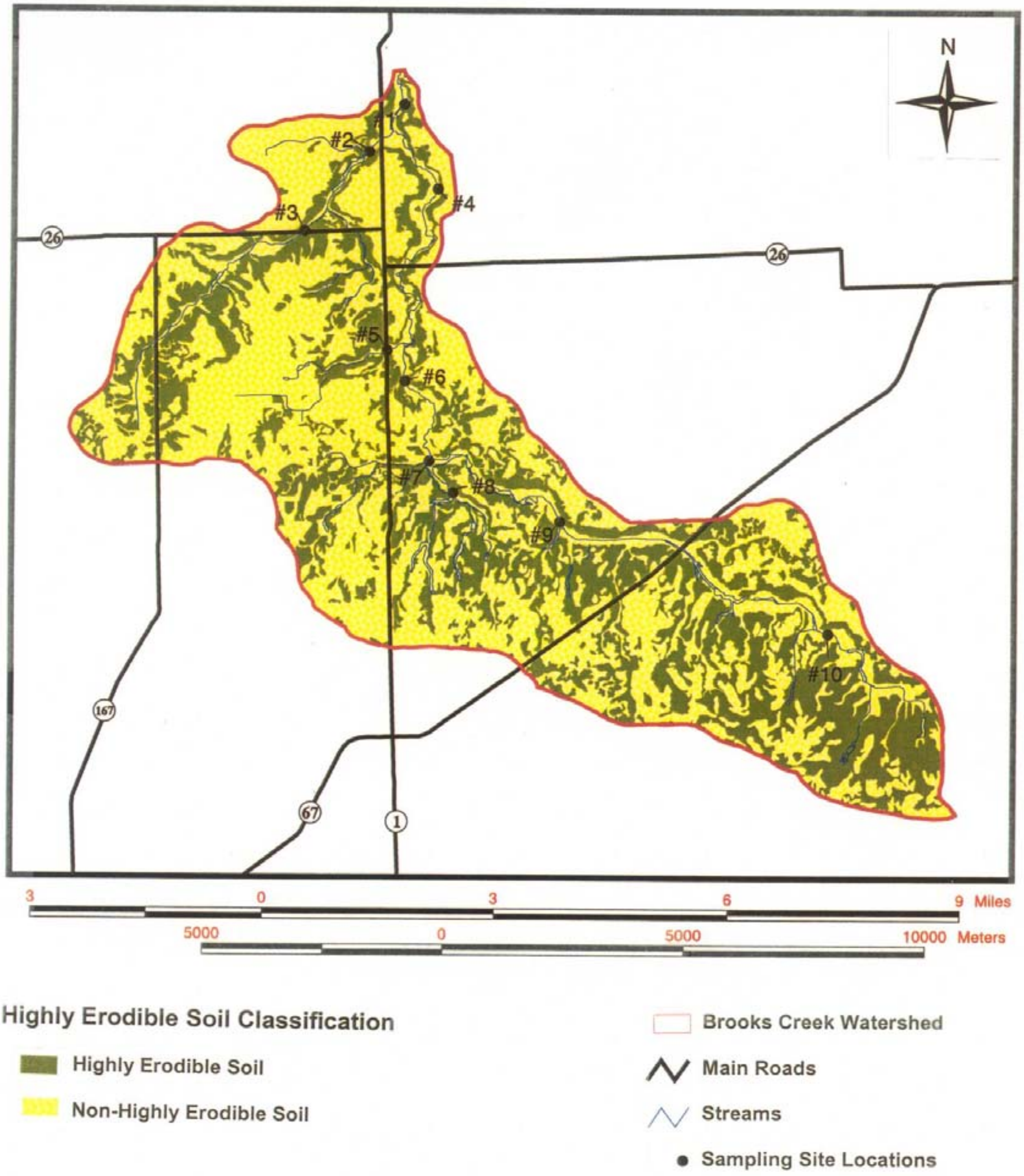


FIGURE 4. Highly Erodible Soils. The map was created by Melissa Clark. Road source: US Department of Transportation. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Sources of other information: Jay County SWCD and USDA Soil Conservation Service.

TABLE 4. Soil units considered highly erodible by the NRCS offices of Jay and Blackford Counties.

Soil Unit	Soil Name	Soil Description
BlA	Blount-Glynwood, thin solum complex	0-3% slopes
EnB3	Eldean clay loam	2-6% slopes, severely eroded
GsB3	Glynwood clay loam	2-6% slopes
GsC3	Glynwood clay loam	6-12% slopes, severely eroded
MaB2	Martinsville loam	2-6% slopes, eroded
MoD3	Morley clay loam	12-20% slopes, severely eroded

Source: 1987 USDA/SCS Indiana Technical Guide Section II-C.

These soil types are limited for certain classes of land use, and erosion hazard is a major management concern. Though not considered highly erodible in all situations, the Blount-Glynwood (BlA) complex tends to be a wet soil. Wetness can lead to soil compaction particularly when the soil is used for agriculture. Eldean clay loam (EnB3) and Martinsville loam (MaB2) are suitable for cultivation as long as erosion problems are managed and actively controlled. Glynwood clay loams (GsB3 and GsC3) make up the largest percentage of highly erodible soils in the Brooks Creek Watershed. Even though both the Glynwood clay loams are unsuitable for cultivated crop production due to erosion hazards, their predominant land use is row crop cultivation. The Glynwood clay loams are suited for hay, pasture, and woodland production. The Morley clay loams are strongly sloping soils of high erosive potential and are generally considered unfit for cultivated crops, pasture, or hay (Kluess, 1986). According to Figures 4 and 7, much of the agricultural land use occurs on highly erodible soils in the watershed. This type of land use on highly erodible, marginal soils has definite implications for the receiving waterway's ability to support its beneficial uses.

Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils. Unlike the soil survey, these fields must be field checked to ensure the accuracy of the mapped soils types. Farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the U.S. Government. Figure 5 shows the location of HEL fields in the study watershed. Approximately, 9,015 acres (3,650 ha) of HEL exist within boundaries of the study watershed. This is about 33% of the Brooks Creek Watershed. Table 5 breaks the information down by watershed. The Stephens Run Subwatershed has the most HEL acreage, and 39.1% of its watershed is mapped as HEL. 60.9% of the Brooks Two Subwatershed is considered HEL. The Jeff Run, Headwaters, and Crooked Creek Subwatersheds also contain large percentages of HEL. Figure 6 demonstrates that more of the HEL is concentrated higher in the watershed. Near the confluence of Brooks Creek with the Salamonie River, the Mouth Area, Bales Ditch Subwatershed, and Brooks One Subwatershed contain the least area mapped as HEL as a percentage of their watersheds.

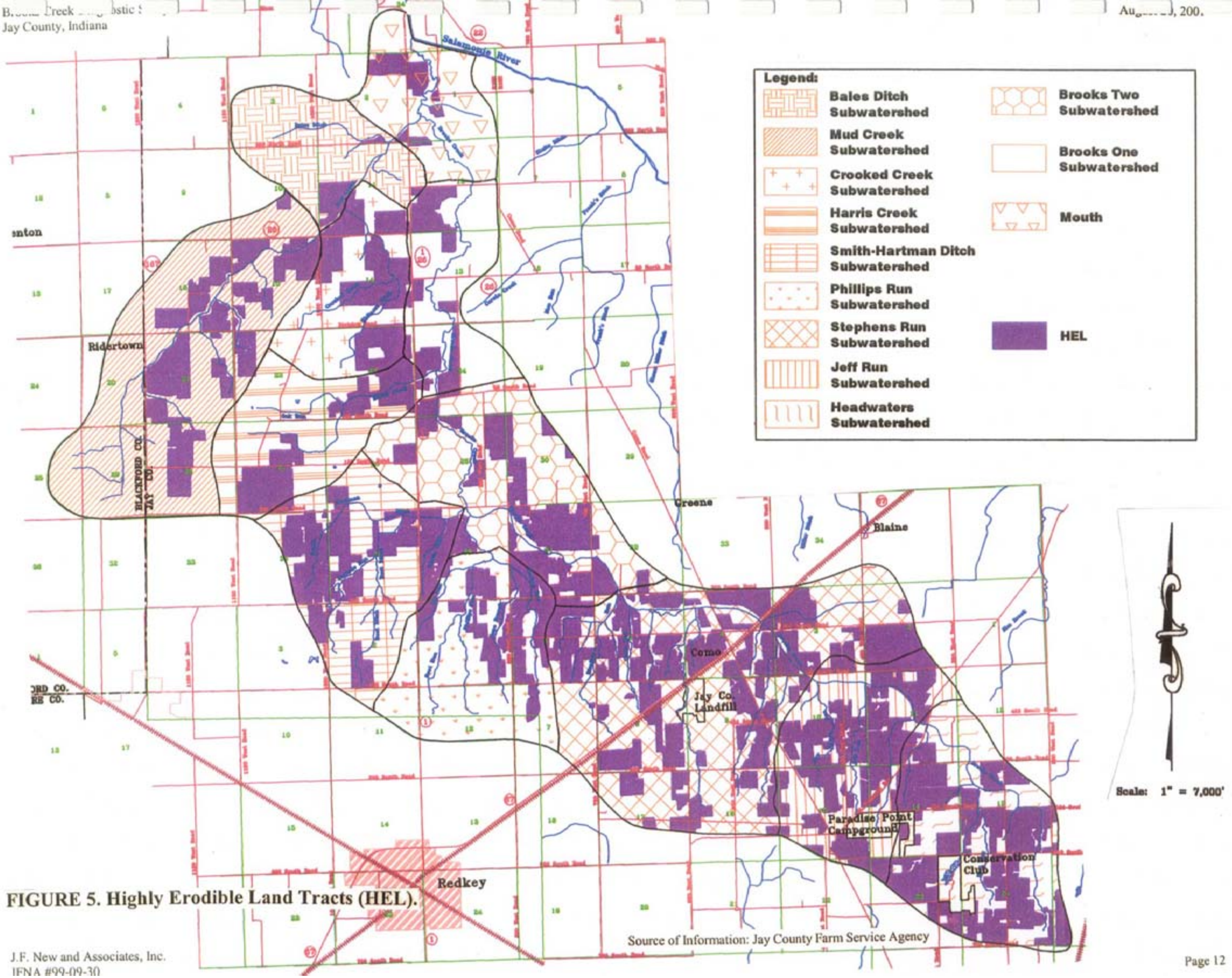


FIGURE 5. Highly Erodible Land Tracts (HEL).

Source of Information: Jay County Farm Service Agency

TABLE 5. Area mapped in highly erodible map units by subwatershed.

Subwatershed	Acres	Hectares	Percent of Watershed
Bales Ditch Subwatershed	82.9	33.6	6.3%
Mud Creek Subwatershed	1032.2	417.9	27.8%
Crooked Creek Subwatershed	601.3	243.4	42.0%
Harris Creek Subwatershed	452.6	183.2	27.5%
Smith-Hartman Ditch Subwatershed	872.7	353.3	39.9%
Phillips Run Subwatershed	494.4	200.1	23.5%
Stephens Run Subwatershed	1984.3	803.4	39.1%
Jeff Run Subwatershed	1024.0	414.6	49.6%
Headwaters Subwatershed	1201.7	486.5	47.3%
Mouth	151.0	61.1	12.2%
Brooks One Subwatershed	298.9	121.0	11.2%
Brooks Two Subwatershed	819.5	331.8	60.9%
Total	**9015.4**	**3649.9**	**32.9%**

Source: Farm Service Agency of Jay County.

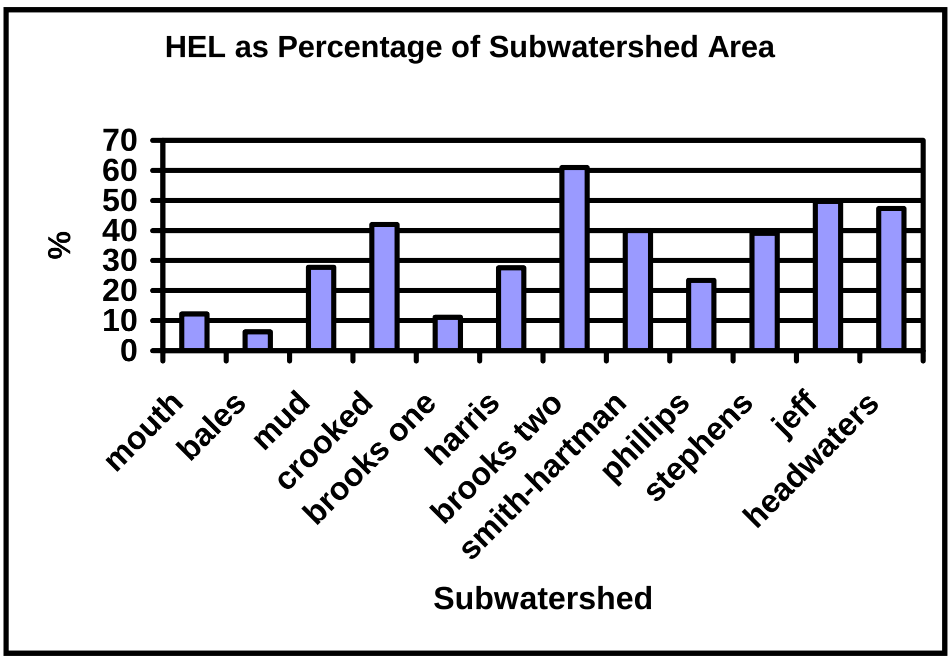


FIGURE 6. Highly erodible land as a percentage of subwatershed area.

Considerations for On-Site Wastewater Disposal Systems

Background Information

Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment in the Brooks Creek Watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area, the chemical properties of the surfaces, soil conditions like temperature, moisture, and oxygen content, and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing the larger pores in the profile even more. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel so rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb them, but retention is not necessarily permanent. During stormflows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

Jay County

Soil conditions such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located on the Wabash Moraine in Wells County are known to perform poorly or to have failed completely. Localized soil-geologic conditions are responsible for most of the problems. In fact, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash End Moraine in an area known as "Buttermilk Ridge", a part of Union Township (Section 14, T.28N., R.11E.). This area is located in the watershed of Eightmile Creek, just north of the Flat Creek Watershed. (Eightmile Creek was the reference stream utilized during this study.) Although no extensive studies have been done in the Brooks Creek Watershed, the Salamonie Moraine and the Wabash Moraine are similar in composition, and many of the same problems may exist in the Brooks Creek Watershed as well.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately or severely limited categories generally requires special designs, planning, or maintenance to overcome the limitations. Table 6 summarizes the predominant soil series located in the study watersheds in terms of their suitability for use as a septic tank absorption field.

TABLE 6. Dominant soil types in the Brooks Creek Watershed and their suitability for on-site wastewater treatment systems.

Symbol	Name	Depth of Water Table	Suitability for Septic Absorption Field
GsB3	Glynwood clay loam, 2-6% slopes, severely eroded	2-3.5 ft	severe: wetness, percs slowly
GsC3	Glynwood clay loam, 6-12% slopes, severely eroded	2-3.5 ft	severe: wetness, percs slowly
Pm	Pewamo silty clay	+1-1 ft	severe: percs slowly, ponding
BlA	Blount-Glynwood, 0-3% slopes	1-3 ft	severe: wetness, percs slowly
MaB2	Martinsville loam, 2-6% slopes, eroded	>6 ft	slight
St	Saranac clay, frequently flooded	0-1 ft	severe: flooding, wetness, percs slowly
Ee	Eel slay loam, frequently flooded	1.5-3 ft	severe: flooding, wetness
Bo	Bono silty clay	+1-1 ft	severe: percs slowly, ponding
MoD3	Morley clay loam, 12-20% slopes,	>6 ft	severe: percs slowly, slope

	severely eroded		
EnB3	Eldean clay loam, 2-6% slopes, severely eroded	>6 ft	severe: poor filter
Wa	Wallkill silty clay, frequently flooded	+1-1 ft	severe: flooding, ponding, percs slowly
Wh	Whitaker silt loam	1-3 ft	severe: wetness

Source: Soil Survey of Blackford and Jay Counties.

The Glynwood clay loams (GsB3 and GsC3), Pewamo silty clays (Pm), and Blount-Glynwood (BlA) soils occur most predominantly throughout the Brooks Creek Watershed. These soil types are severely limited for on-site wastewater treatment because of wetness and slow permeability. It is recommended that systems be: installed with perimeter subsurface drains to lower the water table, installed with an enlarged leach field to offset slow permeability, and constructed when the soil is dry to avoid soil sealing and compaction. Additionally, Pewamo soils tend to pond water causing anaerobic conditions within the soil.

The remaining eight soil types are relatively rare within the Brooks Creek Watershed. While the Martinsville loam (MaB2) is suited for septic leachate treatment, the remaining seven soils are severely limited with respect to waste treatment capabilities. The Saranac clay (St) and the Wallkill silty clay (Wa) soils are deep, nearly level, and very poorly drained. The soils are found in bottom lands and depressions; flooding, ponding, low strength, and slow permeability limits their use for wastewater treatment. Whitaker silt loams (Wh) are unsuitable as well because they are poorly drained and tend to remain wet. Wetness and flooding limit the use of Eel clay loams (Ee) for leach fields. Both the Bonon silty clay (Bo) and the Morley clay loam (MoD3) are soils are low permeability. The steep slope on which Morley clay loam soils occur also limits septic field function. Installing the field on the contour is recommended. Eldean clay loams (EnB3) are very well drained soils. In fact, they are so well drained that they provide poor filtration for wastewater and may compromise ground water quality.

The dominant soil types in the study watersheds have severe limitations for septic suitability (Table 6). Geologic conditions in many parts of the moraine especially along its face and toe are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. Water quality sampling conducted during the current study does not eliminate the possibility that improperly functioning systems may be one possible cause of surface water pollution in the four watersheds. Of particular concern were the Mud Creek and Phillips Run Subwatersheds where *E. coli* concentrations during stormwater runoff exceeded 6,000 col/100ml. The soil survey of Blackford and Jay Counties site slow permeability as a limiting factor for proper septic system function in many of the soils in the study area. Soil impermeability is likely related in some cases to poor waste treatment in this area. A study conducted at the request of the Wells County Health Department in 1995 documented several characteristics present in test pits that are significant contributors to on-site system problems:

1. Sediments in most pits exhibited considerable moisture content at depths of >10 inches. Many upland samples were close to saturation despite mild drought conditions.
2. All pits demonstrated poor soil development. The geologic or biologic processes that develop macroporosity which allows for water movement never occurred.

3. Many pits exhibited a near-surface, virtually impervious "hardpan" within two feet of the surface.

These characteristics indicate severely limited vertical water movement; the primary hydraulic conductivity of clayey lake-based sediments like those found in the test pits is about 10^{-8} cm/sec (less than one inch per year) (Stephenson et al., 1988). In conclusion, the landscape along the north face of the Mississinewa Moraine is very similar to the landscape along the south face of the Wabash Moraine which has thin, eroded, poorly developed soils overlying unfractured lake sediment. These soils types are not conducive to the satisfactory operation of conventional on-site treatment systems.

To address these issues and concerns, development should proceed with caution along the north face of the Mississinewa Moraine. Competent soils scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement and soil development. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetlands may provide a solution in soils that are unsuitable. Some soils may be suitable for alternating field technology which requires that a second field be available to accept effluent while the primary field "rests". Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, or too steep for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned out every 2-5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum. Pressure on septic systems can also be reduced by common water conservation practices like shorter showers and less flushing and rinsing within reason.

Soil Discussion and Summary

The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water leaving the watershed. Highly erodible land is concentrated primarily in the higher areas of the watershed furthest from the mouth. The Brooks Two, Jeff Run, Headwaters, and Crooked Creek Subwatersheds contain the most HEL per unit of watershed acreage. Soil erosion contributes sediment to the rivers reducing water quality downstream and interfering with aquatic habitat and recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production. Additionally, soil eroding from the landscape silts in ditches and drainageways necessitating costly dredging maintenance projects. Not only does the sediment hinder water conveyance, it also provides a nutrient-rich substrate for rooted aquatic plant growth. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Almost all of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields.

This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

According to Mr. Dave Houck, the county sanitarian, soil type and suitability are considered prior to permit issuance for new building projects; and therefore, gross septic system failure due to improper soils is not as much of a problem in new construction. Certified soil scientists dig 60" pits to sample soils for clay content and "moraine characteristics". A more serious threat to water quality according to Mr. Houck is due to homes built prior to 1982 when a county ordinance requiring leach fields was passed. Prior to 1982, homes were outfitted with an aeration system, tank, and tile draining directly to the nearest ditch. The State Department of Health recognized this as a problem in 1978, and most counties passed ordinances in 1981 and 1982. Mr. Houck believes that about 30% of the homes in the Brooks Creek area probably still do not have leach fields. When the Jay County Health Department is notified of a problem, they conduct dye testing and require leach field installation if a problem is identified. Houses that are not retrofitted with leach fields are condemned. According to Mr. Houck, new regulations passed by the Indiana legislature may require counties to pay for septic system retrofitting if homeowners cannot afford the cost.

Pollution from septic tank effluent can affect waterways, the life it supports, and its users in a variety of ways. It can contribute to eutrophication (overproduction) and water quality impairment of lakes and other waterbodies in the watersheds. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watersheds. Swimmers, anglers, or boaters that have body contact with contaminated water may be exposed to waterborne pathogens. This issue may not be as much of a concern for the small tributaries that are the focus of this study, but it is of concern for their receiving waterbody, the Salamonie River. According to the State of Indiana, the Salamonie River should support contact recreation as a beneficial use (IDEM, 2000). Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising well water for drinking.

Land Use

Figures 7, 8 and 9 and Table 7 present land use information for the Brooks Creek Watershed. Land use data was obtained from U.S. Geological Survey Multi-Resolution Land Characterization (MRLC) National Land Cover Data (NLCD). This data was checked with recent aerial photography and in some areas was field checked. Data was last corrected to reflect current conditions in the watershed on March 16, 2000. Land use data for each subwatershed is presented in Appendix 1.

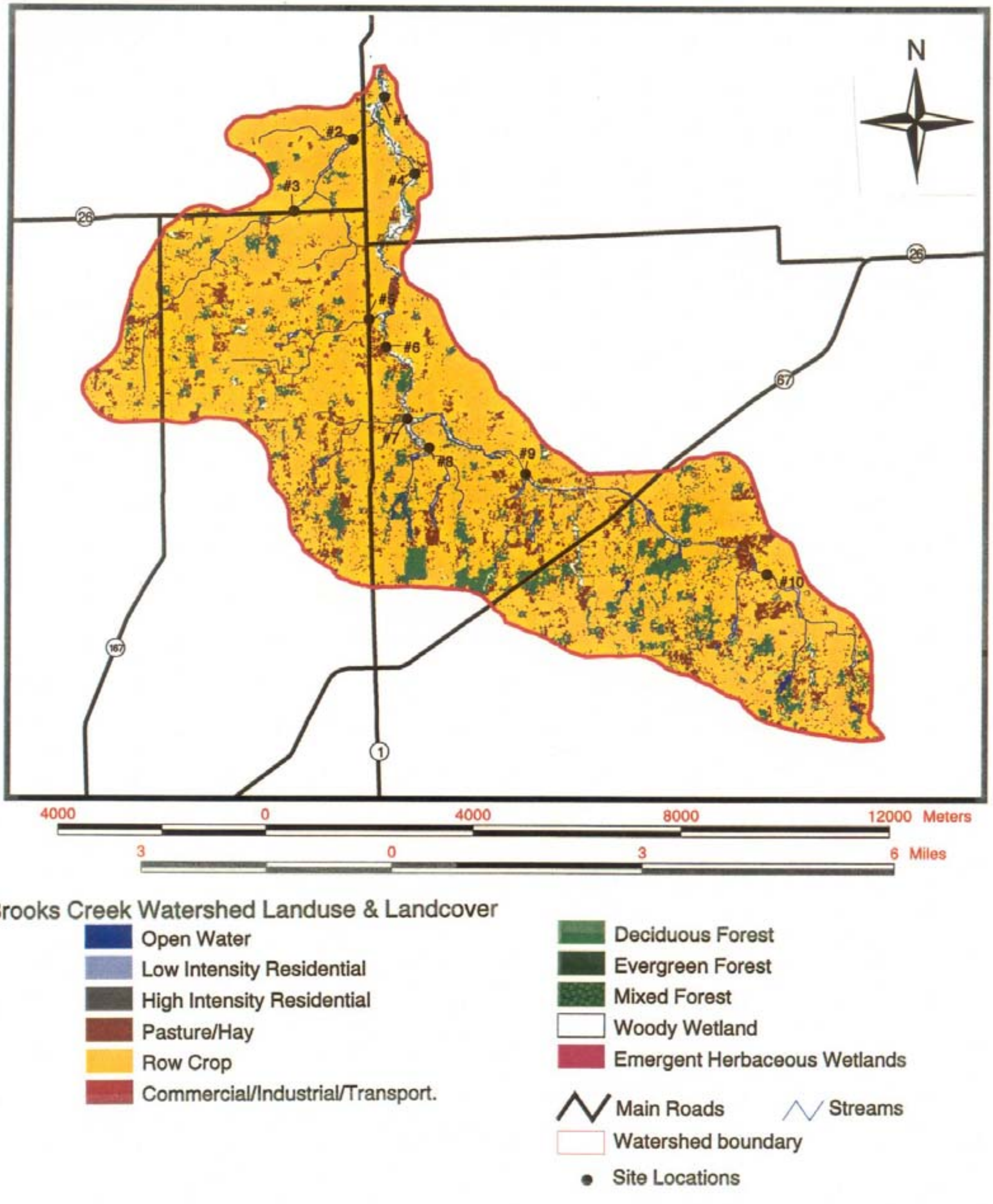


FIGURE 7. Landuse and landcover for the Brooks Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Landuse information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

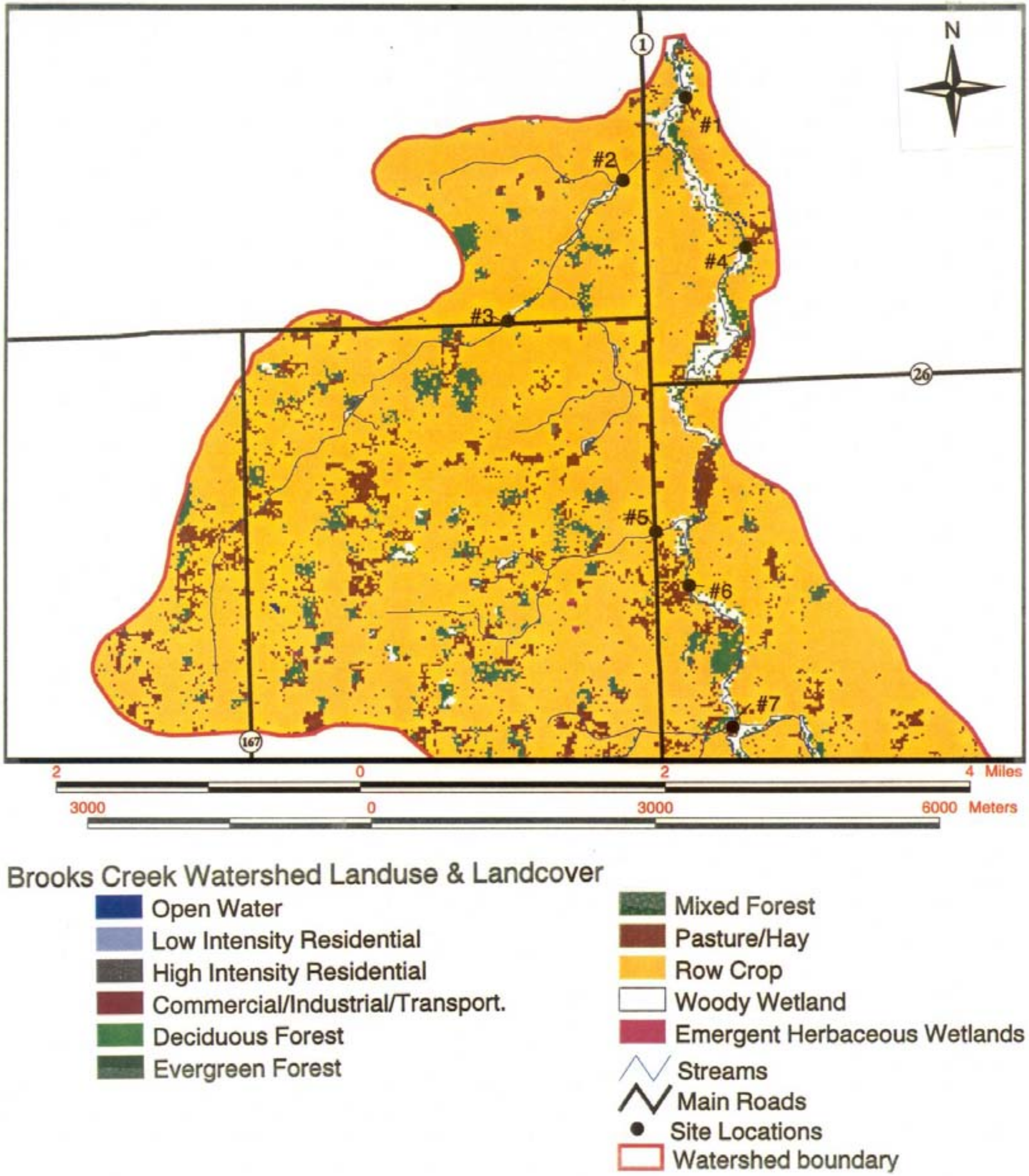


FIGURE 8. Landuse and landcover for the north section of the Brooks Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Landuse information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

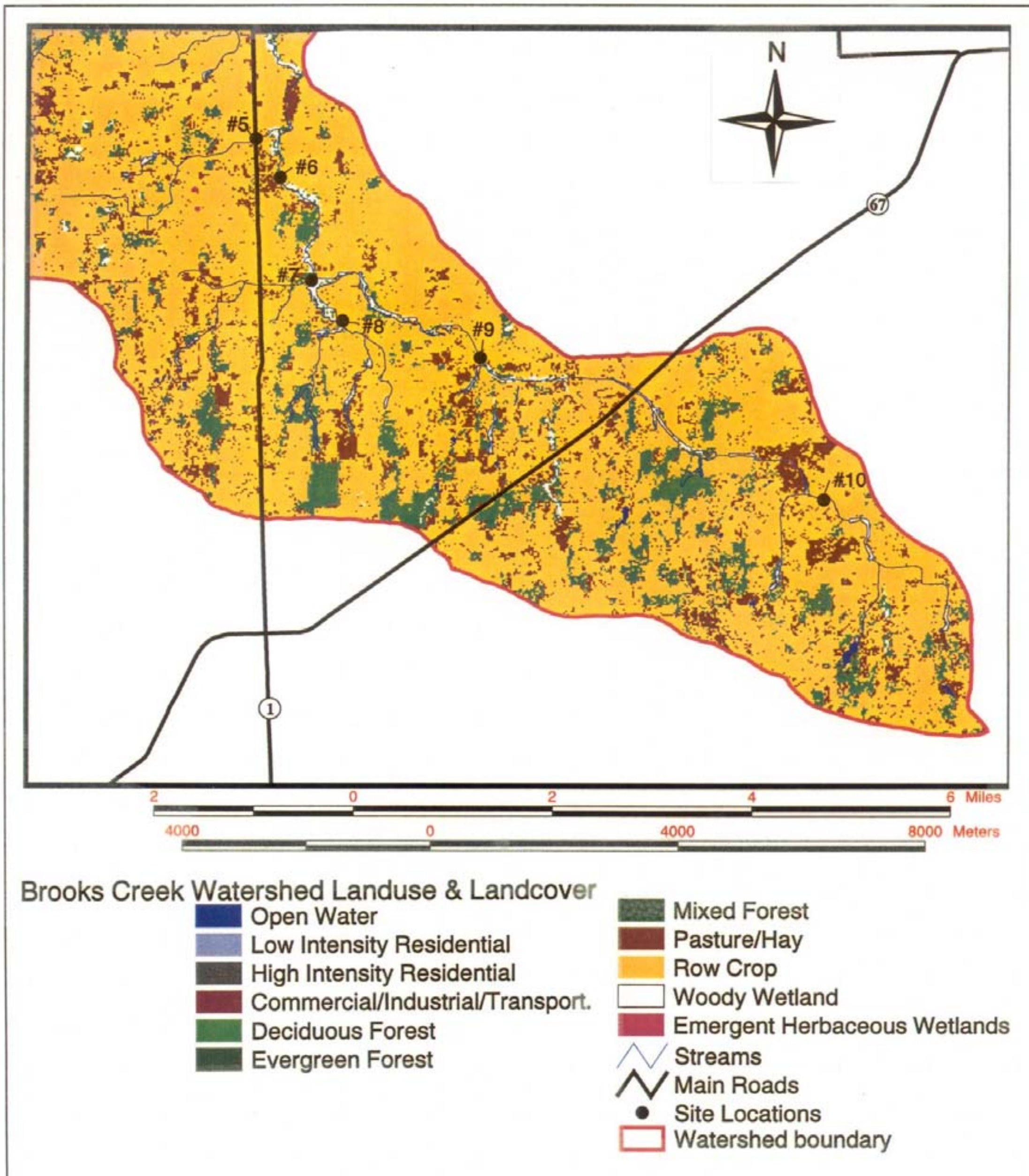


FIGURE 9. Landuse and landcover for the south section of the Brooks Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Landuse information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

TABLE 7. Land use in the Brooks Creek Watershed.

Land Use	Area (acres)	Area (ha)	Percent of Watershed
Brooks Creek			
Open Water	43.8	17.7	0.171%
Low Intensity Residential	1.3	0.5	0.005%
High Intensity Residential	0.7	0.3	0.003%
Commercial/Industrial/Transport	0.7	0.3	0.003%
Deciduous Forest	2,359.0	954.5	9.197%
Evergreen Forest	4.5	1.8	0.017%
Mixed Forest	2.2	0.9	0.009%
Pasture/Hay	3,114.7	1260.4	12.144%
Row Crop	19,742.8	7988.9	76.974%
Forested Wetland	370.6	149.9	1.445%
Emergent Herbaceous Wetland	8.5	3.4	0.033%
Total	**27,440**	**11,109**	**100%**

Approximately 89% of the watershed is used for agricultural purposes, including cropland, pasture, and agricultural woodlots. This percentage is close to the percentage estimated by the U.S. Census of Agriculture (1997) for Jay County (82%). U.S. Census of Agriculture (1997) data also reveals that in 1997, there were 839 farms in Jay County, and 179,800 acres (72,794 ha) were farmed. Agricultural land use is evenly spread across the watershed, and aside from agricultural uses, deciduous forest represents the only other notable land use within the Brooks Creek Watershed. Small tracts of pasture and hay directly border streams in every subwatershed; however, large concentrations of pastureland exist along waterways in the Jeff Run, Stephens Run, Phillips Run, Brooks One, and Mud Creek Subwatersheds. When pastured livestock is allowed direct access to streams, pasture land use is closely coupled with riparian area degradation and increased soil, nutrient, and bacterial runoff. Efforts should be made to exclude livestock from waterways in these critical areas.

Some natural riparian areas still exist like the forested wetlands located in floodplains bordering several sections of Brooks Creek mainstem. Not only do these wetlands help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Due to the small remaining concentration of wetland land use (only 1.44% of the watershed) near the mouth of Brooks Creek, protection of these wetlands is merited. Farmers should also be encouraged to route drainage tiles toward wetland areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage waters directly to the ditch.

Other land uses are very negligible within the Brooks Creek Watershed. Open water, consisting of small ponds, occupies 0.171% of the watershed. The remaining land uses and coverage compose a meager 0.069% including residential areas, evergreen and mixed forests, and emergent herbaceous wetlands.

Soybeans, corn, small grains, and forage are the major crops grown in Jay County. Although exact percentages of each crop were not recorded for the study watershed, 44% of the agricultural fields in Jay County were planted with soybeans and 40% in corn in 2000 (Purdue University Cooperative Extension Service, 2000). It is likely that the study watersheds closely mirror these percentages. Table 8 contains more detailed information regarding percentage and acreage of Jay County fields used to produce different crops and commodities and estimated numbers of cattle in 2000.

TABLE 8. Percent (number) and acreage of Jay County fields with indicated present crop for year 2000. Percentages are taken from a field sampling of points along transects across the County. No data are available for percent or acreage of land in permanent pasture. The last three rows give the number of beef cattle, dairy cattle, and total cattle in Jay County in 2000. Of the 92 counties in Indiana, Jay County ranks 46 with respect to cattle production.

Crop/Commodity	Percent (Number)	Acreage of Land
Soybeans	44 (206)	91,400
Corn	40 (189)	69,700
Small Grains	6 (26)	**
Winter Wheat	**	10,100
Hay/Forage	8 (36)	6,800
Idle (CRP or other programs)	3 (12)	**
Beef Cattle	(1,100)	
Dairy Cattle	(2,300)	
Total Cattle	(8,800)	

Source: Purdue Cooperative Extension Service, 2000 and U.S. Census of Agriculture, 2000.
** indicates that the data was not available.

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil survey of Blackford and Jay Counties, approximately 224,066 acres, or 62% of the total acreage in both counties, meets prime farmland requirements. The land is evenly distributed across the two counties, so much of the land in the Brooks Creek Watershed is classified as prime farmland.

"A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated." (Neely, 1992). Cultivation of more marginal land also results in more damage to the environment. Although the Brooks Creek Watershed is not undergoing rapid urbanization, some new development was noted during the windshield tour (which will be discussed in more detail later). This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land. Again, careful land use and development planning can minimize the need to produce crops on compromised land.

Agricultural Best Management Practices (BMPs)

Approximately 77% of the Brooks Creek Watershed is utilized for agricultural row crop production. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). In addition, the original creation of agricultural land involved draining low wet areas using drainage tiling. This has decreased the storage capacity of the land and increased peak flows of water in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in land erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody. According to the National Research Council (1993), non-point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the USA.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. Filter strips, riparian buffer strips, grassed waterways, land set-asides, conservation tillage, nutrient and pesticide management, and use of erosion control structures are all examples of BMPs. Each is aimed at conservation to help ensure a healthy and productive land through watershed and natural system protection. Programs and BMPs that are currently in use in the study watersheds or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

Introduction

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised by USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and 50% of the cost of establishing permanent land cover. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The New Conservation Reserve Program established in 1997 is targeted at enrolling the most environmentally sensitive land into the program. The program was capped by Congress at 36.4 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland associated with wetlands.

CRP in the Brooks Creek Watershed

A variety of conservation practices are currently in use in the study watersheds. Figure 10 shows the locations of cropland enrolled in the CRP and the years when the tracts will be released from the program. (Please note that some tracts were listed with release dates of 1998, 1999, and 2000. It is not known if these tracts are still enrolled in the CRP. For this analysis, it was assumed that these areas are currently enrolled.) Instead of farming the tracts, landowners have installed filter strips, grassed waterways, and wildlife set-asides. Table 9 contains acreages of land enrolled in the CRP. The largest of the Brooks Creek Subwatersheds, Stephens Run, contains the largest acreage currently enrolled in the CRP. Greater than 10% of the acreages of the Stephens Run, Jeff Run, and Headwaters Area Subwatersheds participate in the CRP. CRP set-asides are fewest in the Brooks One, Phillips Run, Brooks Two, and Mud Creek Subwatersheds. As percentages of their total areas, <3% is enrolled per subwatershed. Bales Ditch and the Mouth Subwatersheds also enlist small percentages of their total areas (1.5 and 4.4%, respectively); however, these two subwatersheds also contain little highly erodible land.

TABLE 9. Acreages of land enrolled in the CRP by subwatershed.

Watershed	Acres	Hectares	**Percent of Watershed**	**HEL:CRP**
Bales Ditch Subwatershed	20.4	8.2	1.5%	24.6:1
Mud Creek Subwatershed	96.9	39.2	2.6%	9.4:1
Crooked Creek Subwatershed	123.9	50.1	8.6%	20.6:1
Harris Creek Subwatershed	113.0	45.7	6.9%	25.0:1
Smith-Hartman Subwatershed	142.5	57.7	6.2%	16.3:1
Phillips Run Subwatershed	7.0	2.8	0.3%	1.4:1
Stephens Run Subwatershed	625.4	253.2	12.3%	31.5:1
Jeff Run Subwatershed	320.5	129.7	15.5%	31.3:1
Headwaters Area Subwatershed	298.4	120.8	11.7%	24.8:1
Mouth	54.4	22.0	4.4%	36.0:1
Brooks One Subwatershed	4.7	1.9	0.2%	1.6:1
Brooks Two Subwatershed	15.8	6.4	1.2%	1.9:1
Total	**274**	**111**	**6.6%**	**17:1**

Source: Farm Service Agency of Jay County.

A comparison of CRP set-asides and HEL designations can help to determine area where management may be best targeted. Most CRP set-asides within the Brooks Creek Watershed overlap with land that is highly erodible (Figure 10). The Mouth, Stephens Run, and Jeff Run Subwatersheds contain the largest amounts of CRP relative to HEL acreage. On the other hand, the Phillips Run, Brooks One, Brooks Two, and Mud Creek have the smallest amount of CRP land protection and treatment when compared to their HEL acreages. The Brooks Two Watershed merits particular concern in that 60.9% of its watershed is highly erodible, but only 1.2% of the watershed (1.9% of the highly erodible land) is delegated to the CRP.

Most CRP designations are concentrated in the lower half of the Brooks Creek Watershed where most of the HEL is located. However, portions of the watershed are notably lacking in CRP participation. The middle of the watershed (Brooks Two and Phillips Run Subwatersheds) and

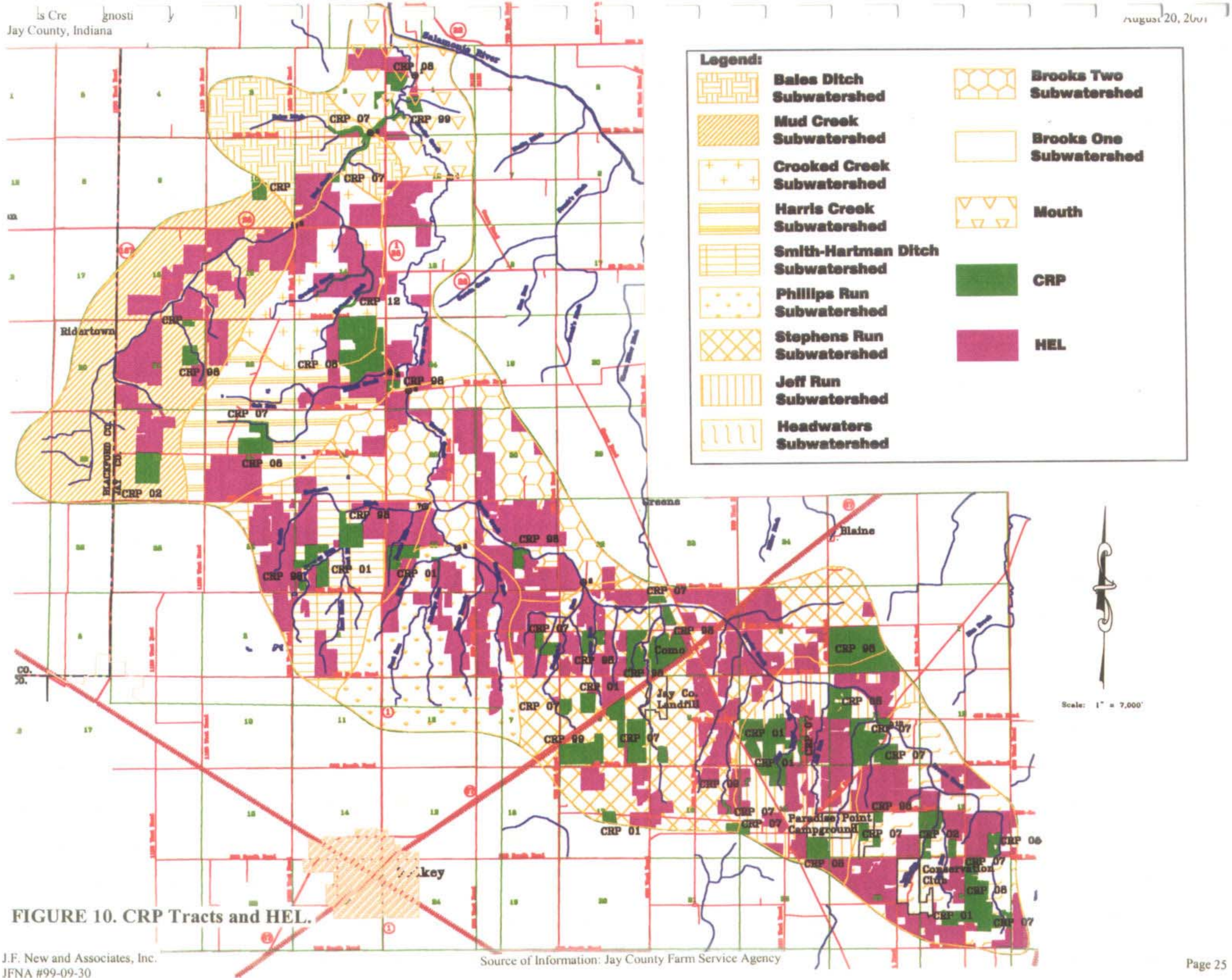


FIGURE 10. CRP Tracts and HEL.

Source of Information: Jay County Farm Service Agency the far western side of the watershed (Mud Creek) should be targeted in future enrollment efforts due to large amounts of unprotected erodible soils.

Many non-protected HEL tracts directly border streams and tributaries to Brooks Creek. This is particularly true for Mud Creek, the main stem of Harris Creek, Smith-Hartman Ditch, Rustic Run, Rope Branch, Cowboy Run, and Bost Run. Additionally, untreated HEL tracts border Brooks Creek itself in the Brooks Two, Stephens Run, Jeff Run, and Headwaters Area Subwatersheds. These tracts would be optimal sites for CRP or other program enrollment.

Conservation Practices

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion. A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths based on intended purpose of the area (NRCS, 2000). The minimum flow length is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loading in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the U.S., the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would be characterized as: native to Indiana, sod-forming, palatable as forage, somewhat cool season so as to grow early in spring when most runoff events occur, hardy, rapidly growing, tolerant of nutrient-poor conditions so as to not need fertilization, able to remain standing throughout the winter providing shelter for wildlife, and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips (NRCS, 2000).) Advantages of planting native vegetation include: 1.) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 11 depicts rooting depths of several native grass species); 2.) many can be hayed for forage use; 3.) natives are hardy and able to withstand various hydrologic regimes; 4.) low maintenance and cost over the long-run due to natural re-seeding processes and hardiness; 5.) low nutrient demand so as to not require costly fertilization which can further impair water quality; 6.) native plants provide wildlife habitat by remaining standing through the winter; 7.) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value. Some disadvantages of establishing native herbaceous vegetation in filter strips also exist: 1.) most native grasses are warm season (except for red top and Virginia wildrye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2.) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3.) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4.) many are quite expensive to produce (see tables below).

The following Tables 10-16 present lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalogue. Mixes should be chosen based on management application and available finances. Table 17 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or applied, an individual's willingness to participate in a set-aside program will have positive effects for water quality.

It is also necessary here to caution landowners who receive federal and/or state cost-share monies for planting vegetation. Certain programs may require special seeding mixtures. For example, Conservation Reserve Program (CRP) filter strips must be planted as per Tables 1 and 2 in the Natural Resources Conservation Service (NRCS) Conservation Practice Standard Code 393. The following eight tables give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

TABLE 10. Recommended native cool season grass species and seeding rates (lbs/acre) for filter strip planting with price/lb per Sharp Bros. Seed Company of Missouri as of February, 2001.

Species	Seeding Rate	Price/lb
Red top	4 lbs/acre	$3.40
Virginia wildrye	4 lbs/acre	$6.90

* If seeding both together, use 2.5 lbs/acre of each.

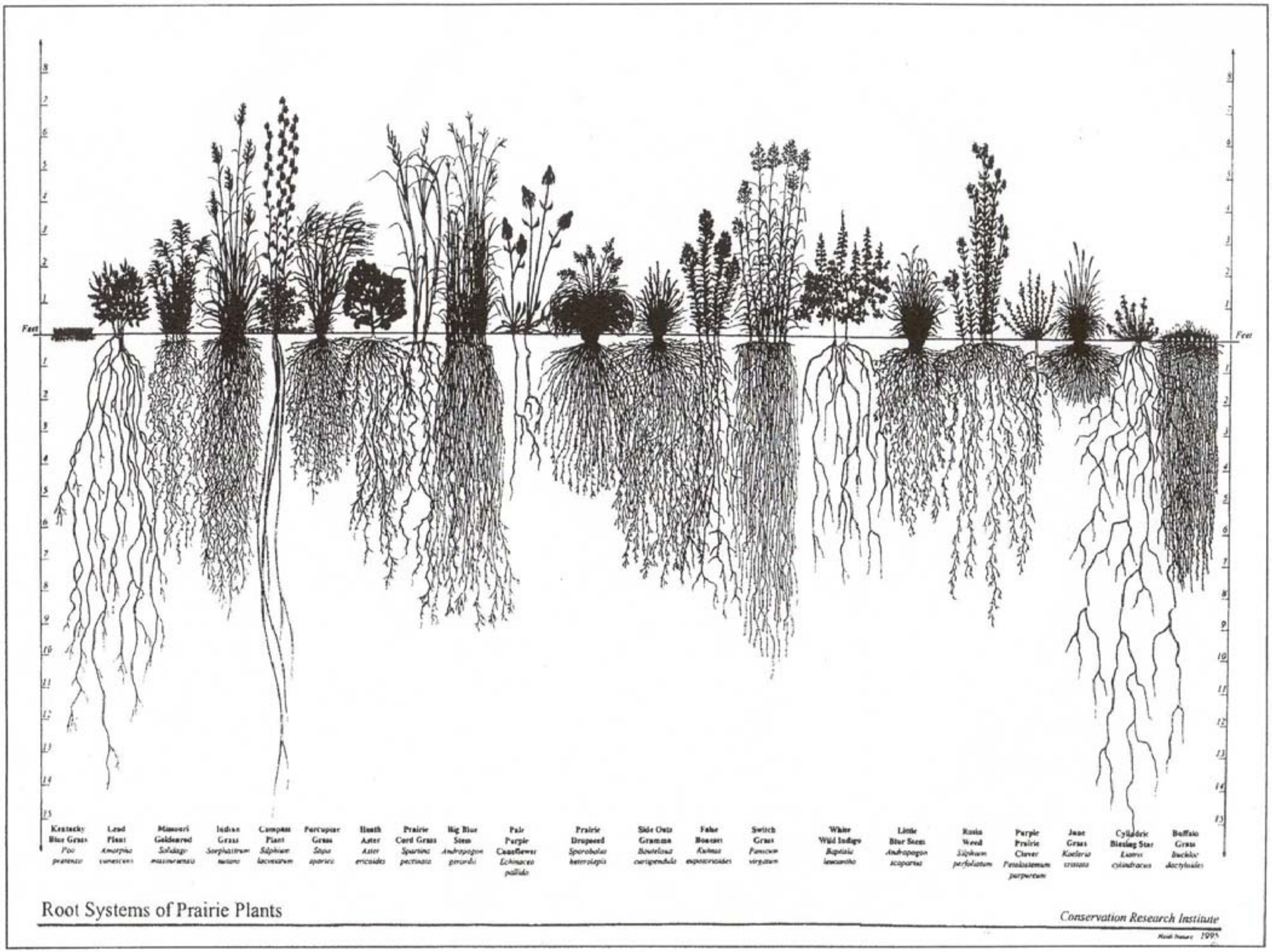


FIGURE 11. Root systems of native prairie plants (from Conservation Reserve Institute, 1995).

TABLE 11. Recommended native legume species and seeding rates (lbs/acre) for filter strip planting with respective prices/lb.

Species	Seeding Rate	Price/lb
Roundhead lespedeza	0.25 lbs/acre	$98.00
Partridge pea	0.25 lbs/acre	$16.10
Illinois bundleflower	0.25 lbs/acre	$6.90
Purple prairie clover	0.25 lbs/acre	$23.00

* These forbes should be sown with native grass seed mixture.

TABLE 12. Recommended native wildflower species for filter strip planting with respective prices/lb.

Species	Price/lb
Black-eyed susan	$22.50
Lanceleaf coreopsis	$27.00
White prairie clover	$137.50
Ashy sunflower	$55.50
Pale purple coneflower	$108.90
Pitcher sage	$72.00
Compass plant	$99.00
Rosinweed	$74.25
Leadplant	$99.00
Purple coneflower	$29.70
Rattlesnake master	$99.00

* These native wildflowers can be seeded in small quantities (<0.25 lbs/acre) along with recommended seeding of native grasses.

TABLE 13. Optimal seed mix for filter strip seeding. This mix is considered optimal based on water quality and soil protection benefits, habitat management benefits, and economy/affordability. Six species are included plus a mix of wildflowers for a total seeding rate of 5.25 lbs/acre.

Species	Seeding Rate
Big bluestem	1.3 lbs/acre
Indiangrass	1.5 lbs/acre
Little bluestem	1.5 lbs/acre
Sideoats grama	0.5 lbs/acre
Switchgrass	0.2 lbs/acre
Mixed wildflowers	0.25 lbs/acre
TOTAL PRICE	**$64.25/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 14. Economy mix for filter strip seeding. This mix also offers native grass species at a more affordable cost. Only three species are included for a total seeding rate of 4.0 lbs/acre.

Species	Seeding Rate
Big bluestem	1.0 lbs/acre
Indiangrass	1.0 lbs/acre
Little bluestem	2.0 lbs/acre
TOTAL PRICE	**$49.90/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 15. Ultra economy mix for filter strip seeding. This mix offers only one native grass species at the most affordable cost. It is recommended that Virginia wildrye and red top be seeded with the switchgrass to increase species and habitat variety and to increase cool season growth in the filter strip.

Species	Seeding Rate
Switchgrass	5 lbs/acre
TOTAL PRICE	**$15-20 lbs/acre depending on variety selected**

TABLE 16. Wildlife habitat management seed mix for filter strip planting or for other areas where managing prairie-type habitat for wildlife is desirable. The total cost for 51.5 lbs for seeding of one acre is $450.00 (J.F. New Native Plant Nursery Wholesale Catalogue, 2001). The temporary grasses serve only to stabilize soils and provide habitat until the permanent, perennial grasses fully develop.

Species	Seeding Rate
Permanent Grasses	5 lbs/acre
Big bluestem	
Little bluestem	
Sideoats grama	
Virginia wildrye	
Switchgrass	
Temporary Grasses	44 lbs/acre
Seed oats	
Annual rye	
Timothy grass	
Native Forbs	2.5 lbs/acre
Butterfly milkweed	
New England aster	
Partridge pea	
Sand coreopsis	
Purple coneflower	
False sunflower	
Rough blazing star	
Wild lupine	
Yellow coneflower	
Black-eyed susan	

TABLE 17. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability.

Species	Reason for Insuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive; excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-95% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of up to 50% have been documented (Conservation Technology Information Center, 2000). Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1) inspection of the project frequently, especially after large storm events; 2) repairing and reseeding of any areas where erosion channels develop; 3) reseeding of bare areas; 4) mowing and removing hay to maintain moderate vegetation height while not mowing closer than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5) controlling trees, brush, and noxious or invasive weeds within the filter; 6) applying fertilizer and lime at rates suggested by regular soil testing.

Riparian Buffers

In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils especially along ditches that pass through mucky or easily erodible soil.

Riparian Management System Model

The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Brooks Creek Watershed. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 12).

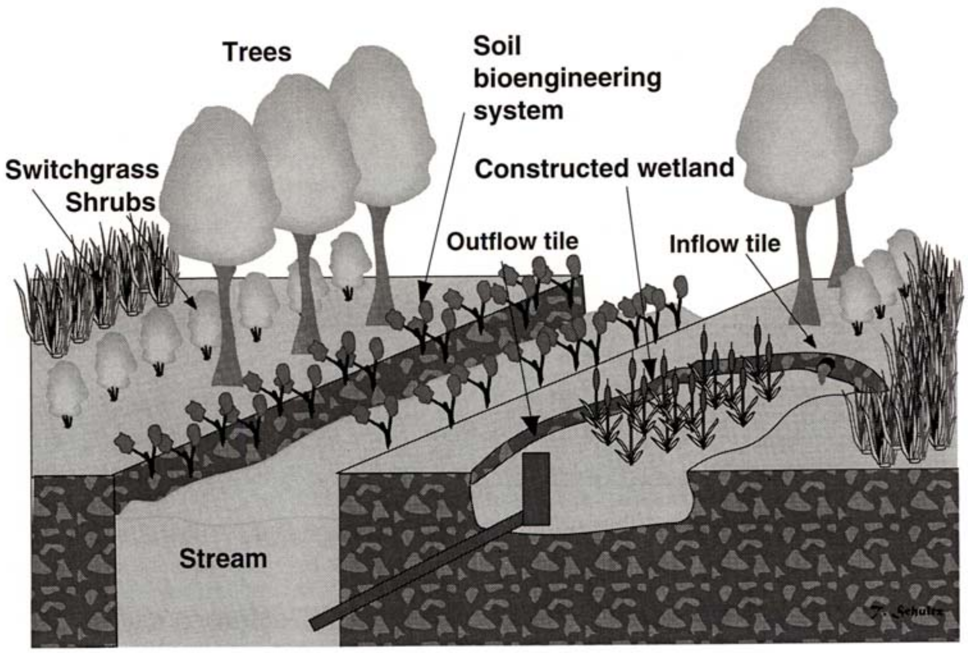


FIGURE 12. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 13): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired buffer physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix 2 includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

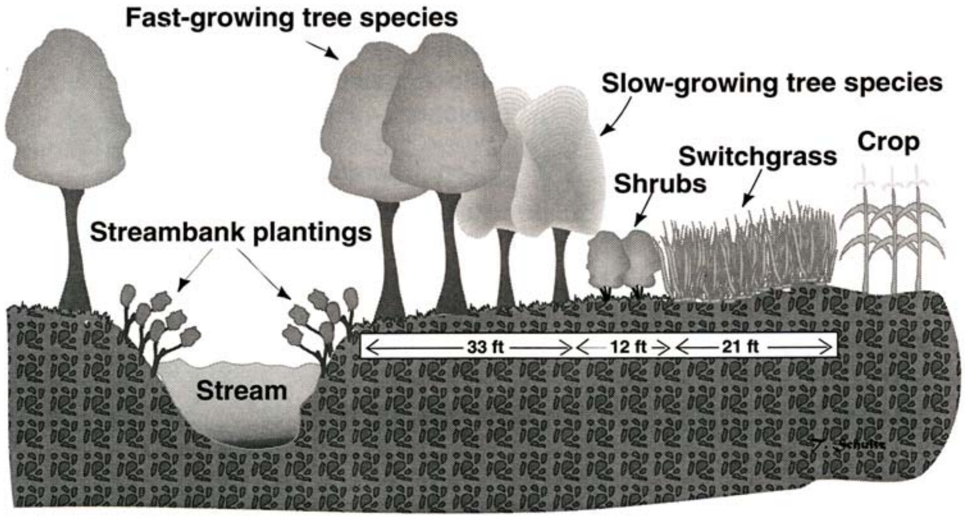


FIGURE 13. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using soil and vegetation bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides a list of stabilization benefits: 1) plant roots hold soils together and in place; 2) above-ground vegetation increases surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffers the channel from abrasion by materials transported from upstream; 4) vegetation induces sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field was tiled into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the structure provides control of water levels (Figure 12). Vegetation was planted in the wetland to jump-start nutrient uptake (See Appendix 2 for photo and Table 18 for a list of plants recommended for wetland planting). Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will provide the adequate water retention time during normal runoff events necessary to remove significant nitrate amounts.

TABLE 18. Plant species suitable for filtration and nutrient uptake in restored or created wetlands.

Grasses	Forbs
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower

Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

* Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.

An important part of any study, the Bear Creek project sites were monitored for success (Isenhart, et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Brooks Creek Watershed. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the Brooks Creek Watershed.

Field Borders

Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in the fall to encourage growth.

Shelterbelts/Windbreaks

Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts.

Grassed Waterways

Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated filter systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense filter. The vegetated filter below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Shallow Water Areas

Shallow water areas within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff.

Wellhead Protection Area

Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Conservation Tillage

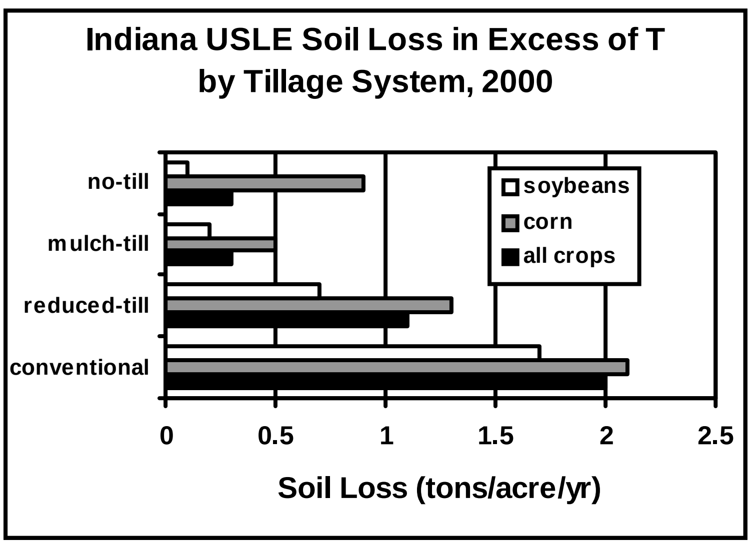
Introduction

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 19 offers description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage. A comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Figure 14 illustrates calculations of soil loss with respect to the "tolerable" amount of soil that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage. Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower TSI scores in ecoregions with higher percentages of conservation tillage. No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life. Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

TABLE 19. Tillage type descriptions.

Type	Description	% Remaining Residue	Conservation Tillage Type?
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	15-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No

FIGURE 14. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year.



Source: Clean Water Indiana Education Program, Purdue University.

Tillage Patterns in the Brooks Creek Watershed

While conservation tillage patterns were not estimated for the study watershed, they are in use throughout Jay County and on many fields within the watershed. Table 20 shows conservation tillage usage patterns since 1990 for Jay County. In general, most cropland used to raise corn is conventionally tilled. The percentage of no-till fields used to grow soybeans is significantly higher at 53%. Eighty-one percent of the fields planted in small grains utilized no-till practices in 2000 (Purdue Cooperative Extension Service, 2000). Of all counties in Indiana, Jay County ranked 62nd and 25th for percent of corn and soybeans, respectively, planted using a no-till system in 2000 (Evans et al., 2000).

TABLE 20. Percent (number) of crop fields with indicated tillage system since 1990 for Jay County. No 1990 data is available for small grain tillage.

Year	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till
Corn					
1990	10 (15)	3 (4)	3(4)	0 (0)	85 (133)
1995	32 (46)	1 (1)	13 (19)	0 (0)	55 (80)
2000	14 (27)	0 (0)	6 (12)	24 (46)	54 (103)
2001	19 (30)	NA	11 (17)	24 (38)	47 (74)
Soybeans					
1990	18 (34)	4 (7)	5 (10)	0 (0)	74 (143)
1995	64 (122)	0 (0)	11 (21)	0 (0)	25 (48)
2000	72 (149)	0 (0)	9 (19)	7 (15)	11 (22)
2001	74 (122)	NA	16 (37)	1 (3)	9 (21)
Small Grain					
1990	14 (9)	0 (0)	83 (52)	0 (0)	2 (1)
1995	67 (26)	0 (0)	0 (0)	0 (0)	31 (12)
2000	81 (21)	0 (0)	0 (0)	8 (2)	12 (3)

* Data did not distinguish between no-till and ridge-till for small grains.
* NA: Information was not available.
Source: Purdue Cooperative Extension Service, 2000.

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, no-till used in a corn-soybean rotation economically outperformed conventional, mulch, and strip tillage systems (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits.

Nutrient Management

Management of nutrients applied in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Soils should be tested every three years, and according to John Knipp of the Jay County Purdue Cooperative Extension agency, most cropland in Jay County is tested once every 3 years (personal communication). Fertilizer should be applied based on realistic yield goals; however, most farmers in Jay County set maximum yield goals resulting in over-fertilization in most years (John Knipp, personal communication). Producers should also make allowances in nitrogen applications for N contributions of any previous legume crops in the rotation or any legume cover crops. Knipp stated that most farmers in Jay County use a soy-corn or soy-wheat rotation and do account for legume N-addition in their fertilizer regimes. Fertilizer adjustment may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields which border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Jay County Purdue Cooperative Extension Agency, fertilizer setbacks are accomplished with filter strips, but the setbacks are not as common as they should be. Producers on highly erodible land in areas of environmental concern tend to be more conscientious with respect to fertilizer application; however, farmers on land of little relief tend to be less aware of critical areas and the practices necessary to conserve these areas (John Knipp, personal communication).

Weed and Pest Management

Weed and pest management results in fewer herbicide and pesticide application at reduced rates and thereby helps to protect the environment by reducing polluted runoff. Proper management entails: 1) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3) planting cover crops to suppress weed growth; 4) planting seed that has been bred for pest resistance during optimal conditions; 5) using insect traps near target crops to track infestations; 6) promoting and attracting natural enemies that help control pests; 7) applying the most effective and appropriate pesticide or herbicide during optimal weather conditions. In general, pesticide dealers in Jay County conduct insect scouting during times of the year when infestations of the European corn-borer and the bean-leaf beetle typically occur. Insecticide is applied according to insect forecasts. In years when little infestation is expected, little if any pesticide is applied (Bill Horan, personal communication).

Resource Management Planning

Resource management planning is an individually-based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with landowners to understand his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze

1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support

5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation

8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (IDNR) and the USDA, most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan.

BMP Summary

Agricultural BMPs are currently used in the Brooks Creek Watershed. While some subwatershed areas within the Brooks Creek Watershed actively enroll significant percentages of HEL in the CRP, the Phillips Run, Brooks One, Brooks Two, and Mud Creek have the smallest amount of CRP management relative to HEL acreage. Due to relative lack of current CRP participation, these areas should be targeted in future sign-up efforts and prioritized for BMP installation. Although some cropland within the watersheds is treated using filter strips and grassed waterways, more participation should be sought and encouraged, particularly on highly erodible tracts that border waterways. Currently, many non-protected HEL tracts directly border Brooks Creek and its tributaries. Conservation tillage is readily used throughout the study watersheds, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999). Comprehensive land management through development of individual Resource Management Plans is highly recommended.

Macroinvertebrates and Habitat

Local, state, and federal databases only contained records of one sampling within the Brooks Creek Watershed. The Indiana Department of Environmental Management (IDEM) Biological Studies Section recorded habitat characteristics and sampled macroinvertebrates in Brooks Creek near its mouth on July 17, 1991. This site closely corresponds to Site 1 chosen for this study, and IDEM's results will be compared with results from this study in the Stream Sampling and Assessment Section. Results of the IDEM habitat analysis and macroinvertebrate counts are given in Tables 21 and 22. In general, habitat quality of Brooks Creek was not found to be conducive to aquatic life, scoring only 45 of a possible 100 points. Additionally, the mIBI score designated the biological health of Brooks Creek as moderately impaired with a metric score of only 2.4 of a possible 8 points. Both the QHEI and the mIBI will be discussed in more detail in the Stream Sampling and Assessment Section.

TABLE 21. QHEI scores for Brooks Creek near its mouth as assessed by the IDEM Biological Studies Section on July 17, 1991.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Maximum Possible Score	20	20	20	10	12	8	10	100
SITE 1-Brooks Creek	10	4	11	7	9	0	4	45

TABLE 22. mIBI scores for Brooks Creek near its mouth sampled by the IDEM Biological Studies Section on July 17, 1991.

	Value	Metric Score
HBI	5.40	2
No. Taxa (family)	12	4
No. Individuals	122	2
% Dominant Taxa	61.5%	2
EPT Index	4	4
EPT Count	28	2
EPT Count/Total Count	0.23	2
EPT Abun./Chir. Abun.	0.37	0
Chironimid Count	75	2
No. Individuals/Square	122	4
mIBI Score		**2.4**

Unionid and Fisheries Studies

Introduction

No mussel or fisheries surveys have been conducted in Brooks Creek Watershed by the Indiana Department of Natural Resources (IDNR), Indiana Department of Environmental Management (IDEM), or the U.S. Fish and Wildlife Service (USFWS). However, the IDNR completed a fisheries survey on the Salamonie River within the reach where Brooks Creek joins the river (Braun, 1980). In 1993 and 1994, Ecological Specialists, Inc. conducted a mussel status and distributional survey on the Salamonie River, and one of the sampling sites was located near the mouth of Brooks Creek. Even though these studies did not take place within the study watershed per say, they do provide useful background information with respect to the receiving waterbody for Brooks Creek. They also offer detail regarding trends within the larger Salamonie River Watershed of which the Brooks Creek Watershed is a part.

IDNR Study

The IDNR conducted a fisheries study beginning above the Salamonie Reservoir to Portland from late July to early October, 1979. The purpose of the study was to determine if suitable walleye spawning habitat was present in the Salamonie River, to determine if walleye remained in the river or migrated downstream to the reservoir, and to document water quality, fish habitat, and species composition in the river. The report noted that the entire watershed above the Salamonie Dam was eradicated of fish in 1965 and then restocked with largemouth bass, smallmouth bass, channel catfish, flathead catfish, and white sucker.

The Salamonie River fish community was sampled near the mouth of Brooks Creek in late July of 1979 using a backpack electroshocker. Temperature, dissolved oxygen (DO), pH, alkalinity, ammonia (NH_3), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate (NO_3^-), total phosphorus (TP), and total suspended solids (TSS) were also measured. The IDNR recorded other information on channel morphology, substrate composition, vegetation, stream cover, erosion, and pollution. Tables 23, 24, and 25 document the study results.

TABLE 23. Fish community present in the Salamonie River near the mouth of Brooks Creek in 1979.

Common Name	Scientific Name	Number	Percent of Sample
Creek chub	*Semotilus atromaculatus*	38	42.7%
Carp	*Cyprinus carpio*	15	16.9%
White sucker	*Catostomus commersoni*	8	9.0%
Suckermouth minnow	*Phenacobius mirabilis*	6	6.7%
Common shiner	*Notropis notropis*	5	5.6%
Blackside darter	*Percina macula*	3	3.4%
Green sunfish	*Lepomis cyanellus*	3	3.4%
Bluntnose minnow	*Pimephales notatus*	2	2.2%
Johnny darter	*Etheostoma nigricans*	2	2.2%
Shiner sp.	*Notropis* sp.	2	2.2%
Black bullhead	*Ameiurus melas*	1	1.1%
Grass pickerel	*Esox americanus vermiculatus*	1	1.1%
River redhorse	*Moxostoma carinatum*	1	1.1%
Silverjaw minnow	*Ericymba buccata*	1	1.1%
Yellow bullhead	*Ameiurus natalis*	1	1.1%

Source: Braun, 1980.

TABLE 24. Chemical characteristics of the Salamonie River near the mouth of Brooks Creek in July of 1979.

Parameter	Measurement
Temperature	73°F (23°C)
Dissolved Oxygen	6.8 mg/l
pH	8.8
Alkalinity	188 mg/l
NH_4^+-N	0.1 mg/l
Biochemical Oxygen Demand	2.0 mg/l
Chemical Oxygen Demand	23.0 mg/l
NO_3^--N	0.8 mg/l
Total Phoshorus	0.33 mg/l
Total Suspended Solids	4.0 mg/l

Source: Braun, 1980.

TABLE 25. Other stream information recorded during the IDNR fisheries survey of 1979 on the Salamonie River near the mouth of Brooks Creek.

Parameter/Characteristic	Description
Average Stream Width	45 ft
Average Stream Depth	1.5 ft

Bottom Materials	sand, gravel, some silt
Shoreline Vegetation	wooded
Instream Cover	scarce
Water Color	muddy
Shade	partly shaded
Aquatic Vegetation	none
Site Description	channelized area, straight with few holes or other cover
Evidence of Erosion or Pollution	bank erosion evident

Source: Braun, 1980.

The report noted two main issues that may negatively affect fish success within the Salamonie River: water level fluctuations and water quality. The banks of the river were “steep” and “high” making them conducive to extreme fluctuation especially during and following storm events. Braun noted that after a storm, it was not uncommon for water levels to rise six feet or more in a matter of a few hours and that water holding storage capacity had been significantly reduced due to drainage of wetland areas for agriculture. The report also documented a general decrease in water quality higher in the watershed as indicated by increasing concentrations of ammonia, nitrate, and total phosphorus. Water quality was assumed to be the primary factor limiting fish production. Water carrying large amounts of sediment was concluded to limit smallmouth bass and channel catfish reproduction in the main channel. The survey failed to document walleye living or reproducing in the river.

The 1979 IDNR report conclusions indicate several problems between Portland and the Salamonie Reservoir that are of concern. Many of these problems probably still exist in the area. Although the survey could not determine if walleye used the river for spawning, no young-of-the-year were caught during the sampling. The report suggests that high sediment loads during spring runoff may result in siltation of substrate spaces and suffocation of eggs. Another issue meriting concern was the decrease in fishery quality as one traveled upstream. Fish habitat was notably degraded or absent, and sewage, industrial waste, and fertilizer spills occurred yearly from Portland to Warren.

The IDNR recommended: 1) working closely with the State Board of Health to improve water quality in the Salamonie River in order to establish a sustainable fishery; 2) stocking channel catfish fingerlings near Montpelier where habitat was available; 3) continuation of area sewage treatment plant monitoring by the State Board of Health.

1993-1994 Unionid Survey

In 1993 and 1994, Ecological Specialists, Inc. conducted a mussel study for the IDNR and the USFWS (Ecological Specialists, Inc. 1995). Although Brooks Creek was not included in the survey, the Salamonie River was sampled at a site near the mouth of Brooks Creek. Table 26 lists the species collected during this study.

TABLE 26. Unionid species collected in the Salamonie River near the mouth of Brooks Creek during 1993 and 1994.

Species	Number Collected	Status of Individual(s) Collected
Alasmidonta marginata	1	subfossil
Amblema p. plicata	1	subfossil
Elliptio dilatata	1	dead, weathered shell
Fusconaia flava	1	dead, weathered shell
Lampsilis siliquoidea	1	dead, weathered shell
Lasmigona complanata	2	live organisms
Pluerobema clava	1	dead, weathered shell
Phychobranchus fasciolaris	1	subfossil
Pyganodon grandis	1	live organism

Source: Ecological Specialists, Inc., 1995.

The number of species found in the Salamonie River was found to be far fewer when compared to the neighboring Mississinewa River. Because headwater sites were found to be statistically different from downstream sties, the report suggests that the species poorness may be due to channelization which removed many subfossil, weathered, and live shells. Weathered and subfossil shells of two federally endangered species were collected, but no live, rare species were sampled. A comparison of historical shells and extant (currently living) shells suggested that mussels species richness had declined throughout the river. On the entire sampled reach, only five live or freshly dead species were collected, and these species are considered highly tolerant. The report concludes that “extensive channelization and water quality problems have severely damaged this stream’s aquatic life”.

Fisheries and Mussel Studies Summary

Although no fisheries or mussel studies have been conducted within the Brooks Creek Watershed, the Watershed’s receiving waterbody, the Salamonie River, has been the focus of two studies. Both of these studies forwarded similar conclusions regarding water quality and habitat suitability for aquatic life. Land treatment and practices within the Salamonie River Watershed have resulted in damages to the aquatic environment that reduce the viability of fish and mussel population that inhabit Salamonie River Waters. Land treatment and conservation within the Brooks Creek Watershed will have positive impacts on fish and mussel community habitat within the larger Salamonie River Watershed.

Natural Communities and Endangered, Threatened, and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed habitat is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the Brooks Creek Watershed are presented in Appendix 3. (For additional reference, a listing of endangered, threatened, and rare species documented in Blackford and Jay Counties are included in Appendix 4). According to the database, the Brooks Creek Watershed supported and may still support Central Till Plain Flatwood Forest communities. This type of forest is listed as a significant, high quality community type in Indiana. The state endangered black-crowned night-heron (*Nycticorax nycticorax*) was noted in 1931 in the reach of Brooks Creek located near the mouth of the Salamonie River. The Wabash belted skimmer dragonfly was also noted in this same area in 1994. This insect is not state or federally listed but is a species associated with more natural habitats.

WATERSHED STUDY

The watershed study is composed of two main components: the watershed investigation and the stream sampling and assessment. The watershed investigation entailed both an aerial tour and a windshield survey of the Brooks Creek Watershed. The stream sampling and assessment involved: 1) stream water quality sampling at nine sites and one reference site during baseflow and during stormwater runoff; 2) a Qualitative Habitat Evaluation Index (QHEI) calculation for all ten sites; 3) a macroinvertebrate Index of Biotic Integrity (mIBI) calculation for each stream sampling site.

Watershed Investigation

Introduction

Targeting areas of concern and selecting sites for future management are the goals of a visual watershed inspection. The Brooks Creek Watershed was toured by airplane in April of 2000 and a windshield survey was conducted in late January of 2001. The results of and observations made during these two surveys are presented below.

Aerial Tour

The aerial tour consisted of flying over the watershed at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos (Figure 15, aer 1-29) are presented by subwatershed. Aerial photo locations are shown on Figure 16.

Mouth Subwatershed. Figure 15 contains an aerial photograph labeled aer1 showing representative impairment within the Mouth Subwatershed. Table 27 lists the exact location of the impaired area shown in the photo and the cause of impairment. (See Figure 16 for mapped location.) An analysis of the photos taken in the Mouth Subwatershed points out that Brooks Creek suffers from straightening or dredging projects. The lack of natural stream meandering and increased flow volumes and velocities have led to bank erosion problems. Bank stabilization (particularly that provided by nature – i.e., landowners allowing natural growth of riparian vegetation) would greatly benefit water quality in this section and throughout the Brooks Creek Watershed.

TABLE 27. Area of concern photographed during the aerial tour along with corresponding cause of impairment for the Mouth Subwatershed. Possible practices that could be used to address the impairment are listed as well.

Stream Name	Photo	Location	Cause	Practice
Brooks Creek and Mud Creek	aer1	facing southeast; junction of Brooks and Mud Creek	eroding banks; no riparian cover	bank stabilization; allow natural riparian vegetation growth

A mobile home salvage yard was also evident from photos taken during the aerial tour in the Mouth Subwatershed (Figure 15, aer1). Although no samples were taken near the area, and it is beyond the scope of the LARE program to sample for pollutants typically associated with vehicle salvage, pollution from the operation could potentially contaminate waterways. Pollutants such as BTEX (benzene, toluene, ethylene, and xylene), CFCs (chlorofluorocarbons), heavy metals, PCBs (polychlorinated biphenyls), and freon could potentially be carried with surface runoff to

FIGURE 15. Aerial tour photos aer4-6.

FIGURE 15. Aerial tour photos aer7-9.

FIGURE 15. Aerial tour photos aer10-12.

FIGURE 15. Aerial tour photos aer13-15.

FIGURE 15. Aerial tour photos aer16-18.

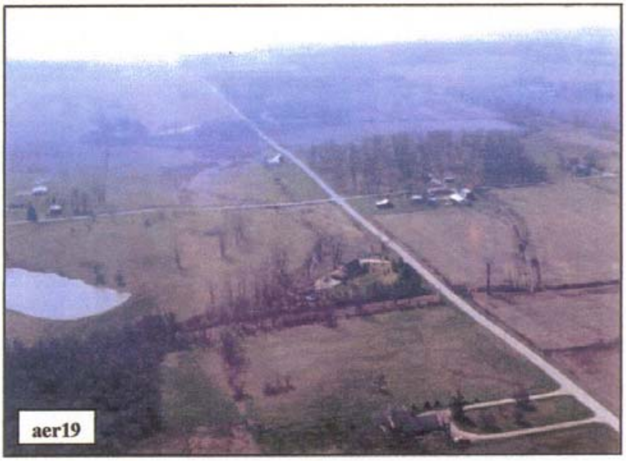


FIGURE 15. Aerial tour photos aer19-21.

FIGURE 15. Aerial tour photos aer22-24.

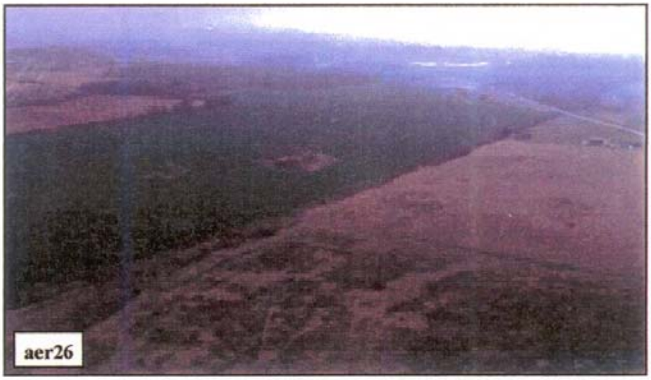


FIGURE 15. Aerial tour photos aer25-27.

FIGURE 15. Aerial tour photos aer28-29.

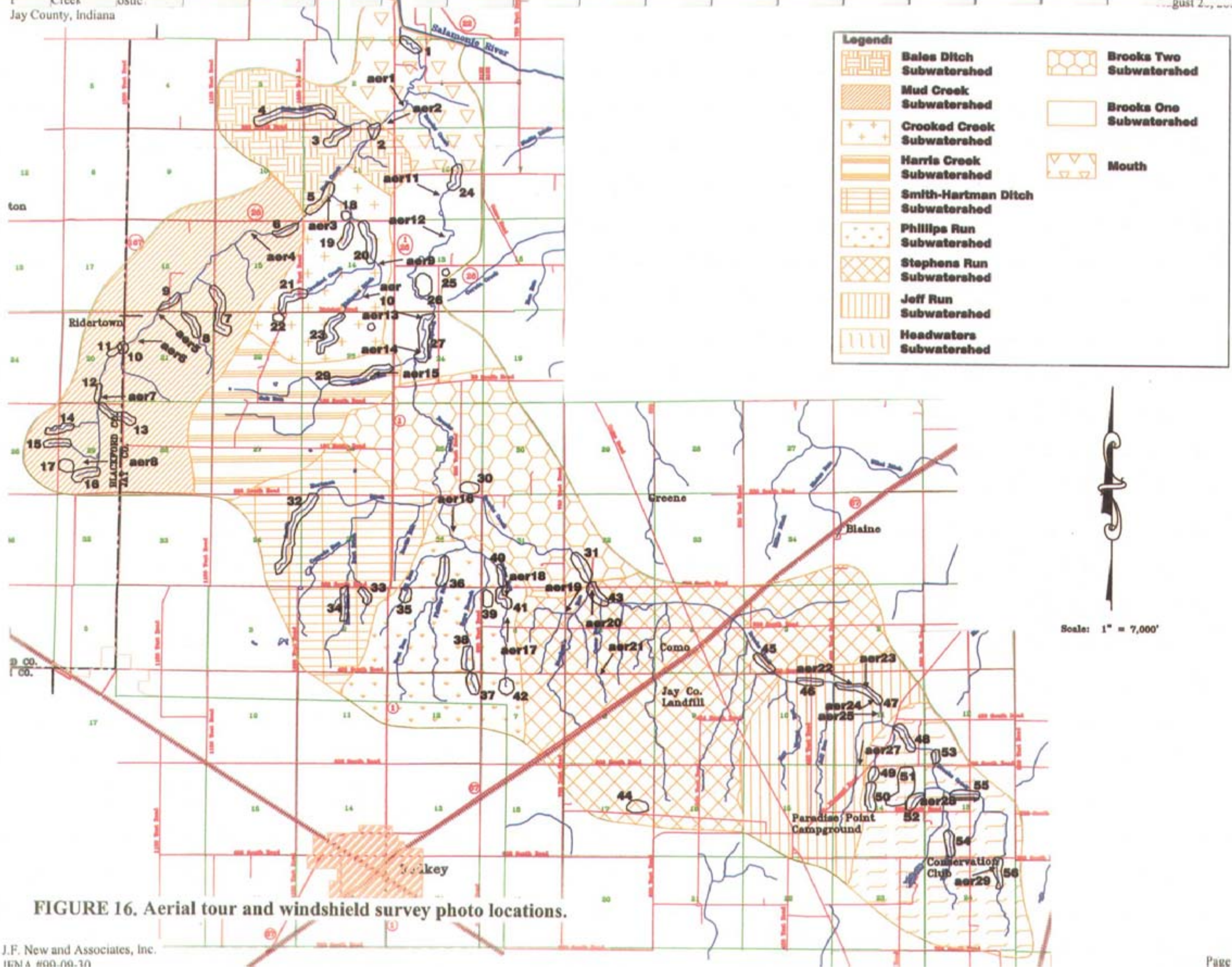


FIGURE 16. Aerial tour and windshield survey photo locations.

the creeks. Bank stabilization and establishment of natural riparian vegetation are strongly recommended to help filter pollutants in runoff. An additional concern involves the soil types on the property where the salvage yard exists. Soil types are Eel clay loam (Ee) and Eldean silt loam (ElA) both of which are severely limited for sanitary landfills due to flooding, wetness, and seepage. The risk for groundwater contamination could potentially be high in this area.

An additional concern regarding the salvage yard involves permits. According to Pam O'Rourke of the Indiana Department of Environmental Management (IDEM) Office of Land Quality Salvage Yard Initiative and Craig Lawson of the IDEM Office of Water Quality Facilities Management Branch, Rule 6 of the Stormwater Rule requires that businesses that deal in automotive salvage file for either a SIC 50-15 or SIC 15-93 permit. SIC 50-15 involves disassemblage of motorized vehicles for the purpose of selling parts, while SIC 15-93 involves recovery and sale of scrap metal only. Once the permit is filed with IDEM, the business must prepare a stormwater pollution prevention plan and must apply for a license with the Indiana Bureau of Motor Vehicles. According to IDEM records, the mobile home salvage yard on SR 1 does not currently hold a permit; whether or not the salvage yard is actually a business is not known.

Bales Ditch Subwatershed. Reaches of stream within the Bales Ditch Subwatershed suffer impairment similar to that documented in the Mouth Subwatershed (Table 28; Figure 15, aer2). Aer2 shows the area where Bales Ditch flows into Mud Creek (Figure 16). Although Conservation Reserve Program (CRP) buffer strips have been installed along both streams, bank instability and erosion are evident. Filter strips are notably failing in several areas due to erosion. Aer3 shows tracts of land in both the Bales Ditch and the Crooked Creek Subwatersheds at the junction of Crooked and Mud Creeks. The complete lack of riparian vegetation or filter strips of any type in this highly erodible area is damaging to water quality. Steep, incised banks are especially notable along the northwest bank of Mud Creek.

TABLE 28. List of locations of impairment photographed during the aerial tour of the Bales Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Bales Ditch and Mud Creek	aer2	facing southwest; northwest of 200 N intersection with SR 1	eroding banks; no riparian cover	bank stabilization; allow natural riparian vegetation growth
Mud Creek and Crooked Creek*	aer3	facing north; north of SR 26 at intersection of Mud and Crooked Creeks	eroding banks; no riparian cover; farming near edge of stream	filter strips; allow natural riparian vegetation growth

* All of the area shown in the photo is classified as HEL.

Mud Creek Subwatershed. The aerial tour also pinpointed several areas of concern within the Mud Creek Subwatershed (Table 29 and Figure 15). Aer4-6 merit special concern due to their location on lands classified as highly erodible. Grazing animals photographed in aer4 should be fenced away from the stream bank particularly since the area is Highly Erodible Land (HEL). In general, natural riparian vegetation growth should be encouraged to stabilize banks, filter sediment and chemical runoff, and provide cover/habitat. Though not highly erodible, the land in aer8 is being farmed in natural swales and drainways. These areas would be ideal candidates for CRP grassed waterway installation.

TABLE 29. List of locations of impairment photographed during the aerial tour of the Mud Creek Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Mud Creek	aer4	facing northwest; west-southwest of 1000 W intersection with SR 26	eroding banks; no riparian cover; farming near edge of stream; grazing animals with direct access to stream	filter strips; allow natural riparian vegetation growth; fence grazing animals from stream
Mud Creek	aer5	facing northwest; intersection of Mud Creek with Division Road	farming near edge of stream	allow natural riparian vegetation growth; filter strips
Mud Creek	aer6	facing west; near intersection of Mud Creek with County Line Road	no riparian cover; farming near edge of stream	allow natural riparian vegetation growth; filter strips
Mud Creek	aer7	facing west; west-northwest of 100 S intersection with County Line Road	farming near edge of stream	filter strips
Mud Creek	aer8	facing west; southwest of 150 S intersection with County Line Road	erosion; no riparian cover; farming near edge of waterway and pond	filter strips; allow natural riparian vegetation growth; grassed waterways

Crooked Creek Subwatershed. Photos of the Crooked Creek Subwatershed show typical bank erosion problems coupled with complete lack of natural riparian vegetation (Figure 15, aer3, 9 and 10). Although some filter strip use is evident in aer10, the area photographed in aer9 is enrolled in the CRP until 2012 yet shows little evidence of Best Management Practice (BMP) installation. Filter strips are very thin, if present at all. Typical BMPs should be used to treat these areas of concern (Table 30).

TABLE 30. List of locations of impairment photographed during the aerial tour of the Crooked Creek Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Whitacre Ditch	aer9	facing west-southwest; west of SR 26 intersection with SR 1	farming near edge of stream; no riparian cover	filter strips; allow natural riparian vegetation growth
Whitacre Ditch	aer10	facing west; northwest of SR 1 intersection with Division Road	farming near edge of stream; no riparian cover; bank erosion	filter strips; allow natural riparian vegetation growth

Brooks One Subwatershed. Aerial photos reveal considerable animal pasture land use adjacent to the stream within the Brooks One Subwatershed (Figure 15; Table 31). Grazing animals with direct access to stream negatively impact the waterbodies in many ways. They contribute directly to erosion by destroying banks when they access the water. They also contribute indirectly to erosion by ingestion and destruction of riparian vegetation. Waste products from the animals load nutrients and bacteria into the waterways. Livestock should be fenced away from the riparian area, and water should be pumped to troughs for the animals.

TABLE 31. List of locations of impairment photographed during the aerial tour of the Brooks One Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Brooks Creek	aer11	facing southeast; east of SR 1	farming and an access road near edge of stream; areas with no riparian cover	filter strip; allow natural riparian vegetation growth
Brooks Creek	aer12	facing southwest; south of aer11	pasture land up to edge of stream; grazing animal with direct access to stream; eroding banks	fence grazing animals from stream
Brooks Creek	aer13	facing east; intersection of Brooks Creek with Division Road	pasture land up to edge of stream; eroding banks	fence grazing animals from stream; allow natural riparian vegetation growth
Brooks Creek	aer14	facing east; northeast of 50 S intersection with SR 1	pasture land up to edge of stream; eroding banks	fence grazing animals from stream; allow natural riparian vegetation growth

Harris Creek Subwatershed. Figure 15, aer15 documents the typical issue of concern for the Harris Creek Subwatershed (Table 32). Marginal, highly erodible land is being farmed and few conservation tools are in use. This combination leads to soil loss, decreased drainage capacity, and water quality degradation.

TABLE 32. Area of concern photographed during the aerial tour along with corresponding cause of and treatment for the impairment in the Harris Creek Subwatershed.

Stream Name	Photo	Location	Cause	Practice
Harris Creek	aer15	facing west; northwest of 50 S intersection with SR 1	farming near edge of stream	filter strips

Brooks Two Subwatershed. Although most of the area bordering Brooks Creek through the Brooks Two Subwatershed has been left in fairly natural condition, artificially increased flow volumes and velocities from land use higher in the watershed have led to incision and bank erosion problems (Figure 15, aer16). This impairment may be irreparable without addressing watershed land use practices. Bank and grade stabilization projects may temporarily deter channel scour in these areas (Table 33).

TABLE 33. Area of concern photographed during the aerial tour along with corresponding cause of and treatment for the impairment in the Brooks Two Subwatershed.

Stream Name	Photo	Location	Cause	Practice
Cowboy Run	aer16	facing south; southwest of 200 S intersection with 800 W	eroding banks	bank stabilization

Phillips Run and Smith-Hartman Ditch Subwatershed. Issues captured by aerial photography for the Phillips Run Subwatershed closely mirror those already discussed for the Harris Creek Subwatershed (Table 34; Figure 15). Highly erodible farmland should be of top priority for BMP installation and watershed land treatment application. Please note that the Smith-Hartman Ditch Subwatershed was not photographed with enough detail to allow diagnosis. It will be discussed more thoroughly in the windshield survey section.

TABLE 34. List of locations of impairment photographed during the aerial tour of the Phillips Run Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Cowboy Run	aer17	facing north; southeast of 300 S intersection with 800 W	farming near edge of stream; no riparian cover	filter strip; allow natural riparian growth
Cowboy Run	aer18	facing south; intersection of Cowboy Run and 300 S	farming near edge of stream; no riparian cover	filter strip; allow natural riparian growth

Stephens Run Subwatershed. Several areas in the Stephens Run Subwatershed could be targeted for BMP installation based on photos from the aerial tour (Table 35; Figure 15). Typical BMPs like filter strip projects and livestock fencing would greatly benefit soil loss from tracts within this subwatershed.

TABLE 35. List of locations of impairment photographed during the aerial tour of the Stephens Run Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Unnamed Tributary and Stephens Run	aer19	facing southwest; intersection of unnamed tributary and 700 W	farming near edge of stream (and possibly pasturing)	filter strips; fence grazing animals from stream
Stephens Run and Brooks Creek	aer20	facing north-northwest; confluence of Stephens Run with Brooks Creek	farming near edge of stream; eroding banks	filter strips
Como Run	aer21	facing southwest; near intersection of Como Run with 400 S	pasture land up to edge of stream and pond; no riparian cover	fence grazing animals from stream and pond; allow natural riparian vegetation growth

Jeffs Run Subwatershed. Although several areas within the Jeffs Run Subwatershed are currently enrolled in the CRP, most areas of concern identified by the tour involve untreated highly erodible tracts (Table 36). Over-grazing and direct animal access to streams is a primary problem as depicted in Figure 15, aer22, 23, and 25. Bank erosion due to past grazing practices is evident in areas that are currently fenced (aer24).

TABLE 36. List of locations of impairment photographed during the aerial tour of the Jeffs Run Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Brooks Creek	aer22	facing southeast; southeast of 400 S intersection with 400 W	eroding banks; pasture land up to edge of stream	bank stabilization; fence grazing animals from stream
Brooks Creek	aer23	facing south; east of aer22	eroding banks; pasture land up to edge of stream	bank stabilization; fence any grazing animals from stream
Brooks Creek	aer24	facing northeast; southeast of aer23	eroding banks	bank stabilization
Brooks Creek	aer25	facing east; west-northwest of 450 S intersection with Mt. Pleasant Road	eroding banks; pasture land up to edge of stream	bank stabilization; fence any grazing animals from stream
Unnamed Tributary to Brooks Creek	aer26	facing south along unnamed tributary to Brooks Creek	farming near edge of stream	filter strips

Headwaters Subwatershed. Typical issues of concern that have already been discussed for other subwatersheds were also documented for the Headwaters Subwatershed (Table 37; Figure 15).

TABLE 37. List of locations of impairment photographed during the aerial tour of the Headwaters Subwatershed. Causes of impairment and practices that could be used to treat them are also listed.

Stream Name	Photo	Location	Cause	Practice
Brooks Creek and Unnamed Tributary to Brooks Creek	aer27	facing east; south of 450 S intersection with Mt. Pleasant Road	farming near edge of stream	filter strips
Brooks Creek	aer28	facing east; just east of intersection of Brooks Creek and 250 W	farming near edge of stream	filter strips
Brooks Creek	aer29	facing east-northeast; southwest of 200 W intersection with 600 S	grazing animals with direct access to stream	fence grazing animals from stream

Windshield Tour

The windshield survey entailed driving the watersheds and assessing the streams where they crossed or were located adjacent to roads. Particular areas of concern were examined more closely by stopping and walking areas within public right-of-way. Results are reviewed by subwatershed with those requiring similar treatment discussed together. Table 38 lists all sites by number and by subwatershed and lists any corresponding photos that were taken of each site while on the tour. Site locations are displayed in Figure 16, and photos appear in Figure 17.

TABLE 38. List of sites and corresponding BMPs compiled during the windshield survey portion of the watershed investigation of the Brooks Creek Watershed.

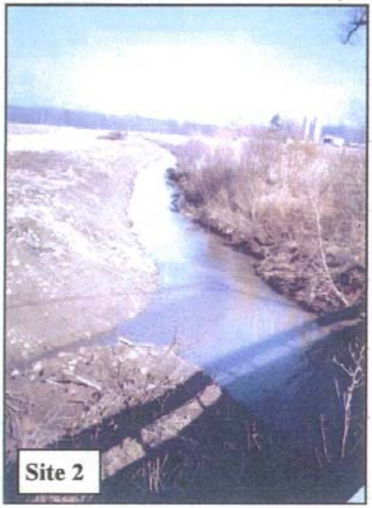
Subwatershed	Site	Recommended BMP
Mouth	1	increase water holding capacity higher in the watershed; bank

		stabilization (See Figure 17, Site 1 for photos.)
Bales Ditch	2†	allow natural riparian vegetation growth; discontinue brushing and dipping projects (See Figure 17, Site 2 for photos.)
Bales Ditch	3	grassed waterway
Bales Ditch	4	filter strip
Bales Ditch and Crooked Creek	5*	filter strip
Mud Creek	6*	filter strip
Mud Creek	7*	filter strip
Mud Creek	8	filter strip
Mud Creek	9*	filter strip
Mud Creek	10	install storm water treatment (See Figure 17, Site 10 for photo.)
Mud Creek	11	filter strip
Mud Creek	12	filter strip and livestock fencing
Mud Creek	13	grassed waterway
Mud Creek	14	grassed waterway
Mud Creek	15	grassed waterway
Mud Creek	16	grassed waterway
Mud Creek	17	grassed waterway
Crooked Creek	18	route storm, gray, and/or black water to appropriate treatment facility
Crooked Creek	19*	grade control structure(s)
Crooked Creek	20*†	filter strip; inspect strips currently in CRP for proper function and specifics
Crooked Creek	21	filter strip
Crooked Creek	22	install a tile riser buffer
Crooked Creek	23*	erosion control, bank stabilization, and riparian area planting on lawns that are currently mown up to the stream edge
Brooks One	24	allow natural riparian vegetation growth; discontinue brushing and dipping projects (See Figure 17, Site 24 for photo.)
Brooks One	25	install a tile riser buffer
Brooks One	26*	grassed waterway(s)
Brooks One	27	filter strip and livestock fencing
Harris Creek	28*†	install a tile riser buffer
Harris Creek	29*	filter strip
Brooks Two	30	install a tile riser buffer; grassed waterway and filter strip along drainway
Brooks Two	31*	filter strip
Smith-Hartman Ditch	32*	grassed waterway
Smith-Hartman Ditch	33	inspect grassed waterway (built 10-12 years ago) for proper function
Smith-Hartman Ditch	34	grade control stucture
Phillips Run	35*	filter strip

Phillips Run	36*†	allow natural riparian vegetation growth; discontinue brushing and dipping projects (See Figure 17, Site 36 for photo.)
Phillips Run	37	widen existing narrow filter strip
Phillips Run	38*	grade control structure; widen existing narrow filter strip
Phillips Run	39*	filter strip
Phillips Run	40*	filter strip
Phillips Run	41*	seed installed filter strip on west side of Cowboy Run
Phillips Run	42*	grassed waterway installation is in progress
Stephens Run	43*	filter strip
Stephens Run	44	drop structure into grassed waterway
Stephens Run	45*	grade control structure; bank protection; filter strip
Jeffs Run	46	bank stabilization; grade control
Jeffs Run	47*†	filter strip
Headwaters	48	filter strip
Headwaters	49*	rebuild grassed waterway
Headwaters	50*	bank stabilization; grade control
Headwaters	51*	widen grassed waterway and filter area
Headwaters	52*	filter strip
Headwaters	53	bank stabilization
Headwaters	54	filter strip
Headwaters	55*	filter strip
Headwaters	56	filter strip and livestock fencing (See Figure 17, Site 56 for photo.)

* indicates that the site overlaps with HEL.
† indicates that the site is currently enrolled in the CRP according to the Farm Service Agency.

FIGURE 17. Windshield survey photos of Site 1.



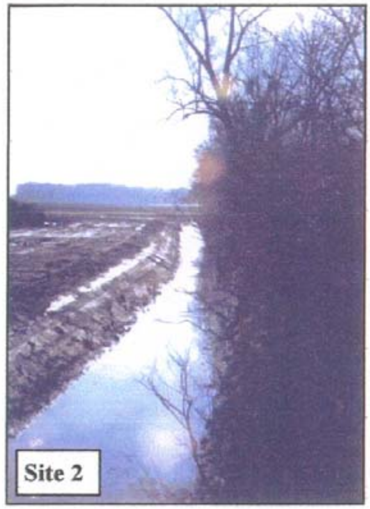


FIGURE 17. Windshield survey photos of Site 2.

FIGURE 17. Windshield survey photos of Sites 10, 24, 36, and 56.

Mouth Subwatershed. The windshield survey near the mouth of Brooks Creek revealed damage attributable to decreased water holding capacity higher in the watershed. Especially during storm flows, artificially enlarged volumes of water moving at increased speeds tear out banks downstream. A private landowner whose acreage borders Brooks Creek near its mouth (just north of sampling site 1) is rapidly losing land and the trees growing on that land. At some point, he fears losing a pond which is near the creek. Figure 17, Site 1 depicts some of the destruction in this area. Although bank armoring and stabilization may temporarily hold the problem in check, damage cannot be permanently prevented without increasing water holding capacity within the watershed.

Harris Creek, Brooks Two, Smith-Hartman Ditch, Stephens Run, Jeffs Run, and Headwaters Subwatersheds. BMP treatment of certain sites within all subwatersheds in the Brooks Creek Watershed is recommended (Table 38). Most issues of concern identified during the windshield survey in the Harris Creek, Brooks Two, Smith-Hartman Ditch, Stephens Run, and Jeffs Run Subwatersheds can be treated with conventional BMPs or combinations of different BMPs. Filter strips and grassed waterways are two common BMPs that could benefit these subwatersheds. Additionally, tile riser buffer areas are recommended for specific sites in the Harris Creek and Brooks Two Subwatersheds. Grade control and bank stabilization have various applications within the Smith-Hartman Ditch, Stephens Run, and Jeffs Run Subwatersheds. The need for livestock fencing to prohibit stream access was also noted in several subwatersheds (Figure 17, Site 56). Maintenance of BMPs that have been installed in the past is also important. Maintenance needs were documented in several subwatershed areas (Table 38). The Stephens Run and Jeffs Run Subwatersheds each contain possible point sources of pollution, the Jay County Landfill and the Paradise Point Campground. Although neither site was closely studied, no obvious reason for concern was noted at either site. However, improperly treated landfill leachate and septic system effluent can adversely impact water quality. Water sampling beyond the scope of this study could be used to determine the impact these two sites have on water quality.

The Stephens Run Subwatershed also contains the Jay County Landfill. Waste Management of Indiana, L.L.C. currently holds a solid waste facility permit issued by the IDEM Office of Land Quality (John Hale, permit manager) for 480 acres of land near the intersection of CR 140 and SR 76. The solid waste permit requires groundwater monitoring, and measured parameters must fall below set criteria or otherwise a violation is issued. On March 14, 2002, J.F. New and Associates reviewed 10 years of groundwater quality data, and no violations of permitted levels were noted indicating that for the past 10 years the Jay County Landfill has been operating in full compliance of its permit. All refuse deposited at the landfill site is placed within a sealed liner, and based on the groundwater quality data, no liner breaches are evident. The liner is composed of three feet of re-compacted clay covered by a 60-mil high-density polyethylene plastic liner. Upon review of the groundwater quality data, levels of some constituents were higher than background levels indicating that some constituents do percolate through the liner; however, levels are below permitted limits. Although no sampling was conducted near the landfill during this study, it should be noted that the landfill does not currently hold a National Pollution Discharge Elimination System (NPDES) permit indicating that the landfill does not discharge effluent to a surface water. According to previous site visits by J.F. New & Associates staff and according to Brad Eisenhart of Waste Management of Indiana, L.L.C., no discharge enters

Brooks Creek tributaries directly although silt from recently disturbed areas could be carried to the creek with runoff. A few areas of modest erosion have been observed near the creek; however, Mr. Eisenhart noted that they utilize sediment basins, silt traps, and seeding practices to minimize erosion.

It should also be noted that the Jay County Landfill is expanding the area within the 480-acre parcel that contains refuse. During expansion within the 480-acre site, approximately 2 acres of jurisdictional wetlands will be destroyed. Wetland mitigation at ratios of 2:1, 3:1, and 4:1 (depending upon impact) will occur at a site south of the 480-acre site. During the expansion, Waste Management of Indiana, L.L.C. also plans to realign the stream channel that passes through the southwest corner of the property. Stream bank and riparian corridor stabilization and protection are part of the plans as well.

Mud Creek Subwatershed. Aside from typical BMP recommendations, an additional issue within the Mud Creek Subwatershed merits discussion. At Site 10, located at the intersection of Mud Creek with County Line Road, storm water enters the creek through a drainpipe on the bridge (see Site 10 photo). Runoff directly entering the creek from roadways may carry pollutants and toxins like petroleum products and salt. At the minimum, water should be routed to vegetated filter areas before being introduced to the creek.

Crooked Creek Subwatershed. In addition to filter strips and grade stabilization recommendations, wastewater treatment and lawn erosion need to be addressed in the Crooked Creek Subwatershed. At Site 18 a pipe routing water directly from a house was noted. Even though the pipe was not closely inspected, storm water and wastewater should be conveyed to the appropriate treatment facility instead of directly to the stream. Along Whitacre Ditch (Site 23), several maintained lawns that border the ditch are eroding due to lack to riparian cover and stabilization. Erosion control, bank stabilization, and planting projects in this reach are recommended. Residents in the area should be encouraged to allow natural riparian vegetation growth.

Bales Ditch, Brooks One, and Phillips Run Subwatersheds. Impacts due to county drainage projects were evident at Site 2 in the Bales Ditch Subwatershed, Site 24 in the Brooks One Subwatershed, and Site 36 in the Phillips Run Subwatershed (see Figure 17, Sites 2, 24, and 36 for photos). Photos taken in the Bales Ditch Subwatershed visually document the water quality impacts of channelization. The sediment plume in photos of Site 2 just north of 200 N is a direct consequence of these drainage activities. Drainage projects would not be necessary if soil remained on the land and out of waterways. The immediate and long-term contribution of sediment loading to the waterways caused by these projects should be recognized. Encouraging natural riparian growth and abandoning brushing and dipping projects would result in better drainage, better water quality, and healthier aquatic ecosystems.

Watershed Investigation Conclusion

The goal of the watershed investigation was to target areas of concern and select sites for future management. The aerial tour pointed out that all streams have been heavily impacted by channelization and dredging projects. The already unstable banks coupled with crop production up to the ditch edge has led to and will continue to cause soil erosion. This siltation then requires costly drainage projects. Both the erosion and the dredging projects also wreak havoc on the biota in, around, and downstream of the location. According to the aerial tour photos, many sites within the watershed can be treated with combinations of filter strips, riparian area fencing, and bank stabilization. Natural riparian vegetation growth should be encouraged. The aerial tour also revealed some areas where land enrolled in CRP shows little or no evidence of actual BMP installation or program participation. This is of concern and should warrant further investigation. The windshield survey pinpointed the locations of some smaller, more localized problems like areas that have been debilitated by cleaning projects, areas of direct livestock stream access, and storm water treatment, grassed waterway, tile riser buffer, and in-stream structure needs. It is important to note that many problems downstream could be alleviated by increasing water holding capacity higher in the watershed. Potential wetland and shallow water pond restoration sites were discussed during the windshield survey.

By overlaying the results of mapping exercises and locations targeted by the watershed investigation, several areas within each watershed deserve prioritization and special consideration. All site locations for potential projects or treatment that overlap with highly erodible land are marked with an asterisk in Table 38. These projects should take priority over projects on land of lower erosion potential. Phillips Run and Headwaters Subwatersheds have the most identified projects that overlap with HEL.

Stream Sampling and Assessment

Introduction

The stream assessment portion of the watershed study consisted of water chemistry sampling during base flow and during a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at 10 sites in the Brooks Creek Watershed and at one reference site in the Eightmile Creek Watershed (Figure 18). The stream assessment study provides information that can be analyzed to determine water quality and aquatic habitat impairment. The data can be used to guide a prioritization of management actions and direct those actions toward the most critical areas.

Sampling Locations

Ten sampling sites were strategically chosen throughout the Brooks Creek Watershed. The sites were selected based on accessibility and relative amount of information that could be obtained for each subwatershed. The reference site on Eightmile Creek was chosen because area SWCDs had recently targeted the creek and its watershed with several work projects. The Jay and Wells County SWCDs felt that Eightmile Creek would be a good “measuring stick” by which to compare streams within the Brooks Creek Watershed. Streams within the Brooks Creek drainage could then be evaluated for impairment relative to Eightmile Creek.

An ideal reference site would have a relatively undisturbed watershed with little channel alteration and would meet all criteria listed in Table 39. Because of extensive human activities throughout the watersheds in the study area, a reference site meeting all of the criteria in Table 39 could not be located, and as will be discussed later, Eightmile Creek served poorly as a reference site. Because of this, the usefulness of comparisons between the reference and study sites was somewhat limited. Doug Nusbaum of the Indiana Department of Natural Resources (IDNR) suggested that Stoney Creek, which had been the control site for a study in the Wolf Creek Watershed, may make a better reference point for future studies in the area. The Muncie

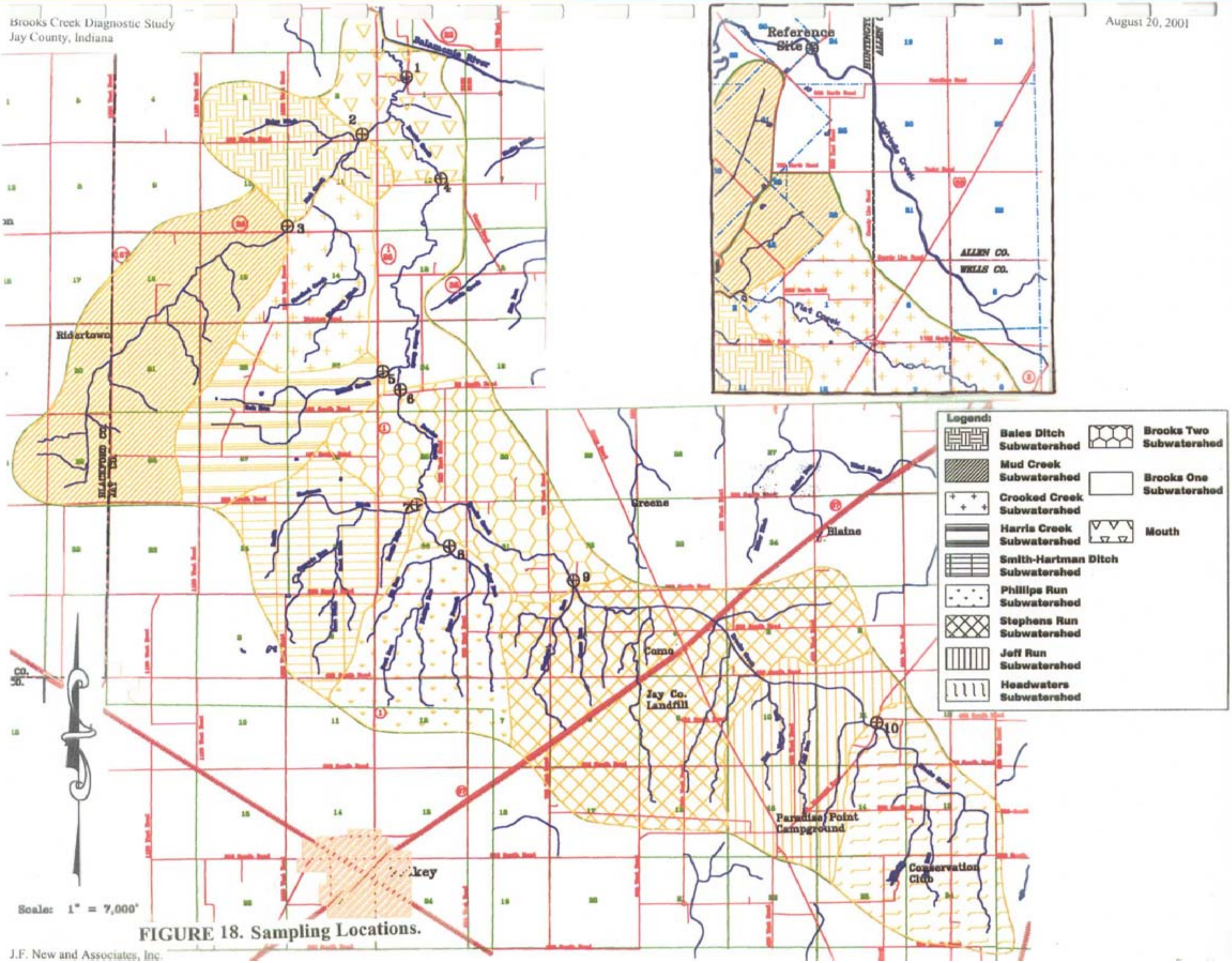


FIGURE 18. Sampling Locations.

Sanitary District has regularly monitored the fish and macroinvertebrate communities of Stoney Creek. The creek is known to support healthy biological communities and high quality habitat. Table 40 provides more detailed sampling location information for each of the ten sites and the reference site.

TABLE 39. Minimum criteria for stream reference sites. Source: Plafkin et al., 1999.

Example Criteria for Reference Sites (Must meet all criteria)
• **pH >=6; if blackwater stream, then pH <=6 and DOC >8 mg/l** • **Dissolved Oxygen >= 4 ppm** • **Nitrate <=16.5 mg/l** • **Urban land use <=20% of catchment area** • **Forest land use >=25% of catchment area** • **Instream habitat rating optimal or suboptimal** • **Riparian buffer width >=15m** • **No channelization** • **No point source discharges**

TABLE 40. Detailed sampling location information for the Brooks Creek Watershed.

Site #	Stream Name	Related Subwatershed	Road Location	Place Sampled	USGS Quad	UTM Coordinates
Ref	Eightmile Creek	Eightmile Creek	intersection with North Mayne Road	downstream of bridge	Zanesville, Section 24, T29N, R10E	639164.04 x 4534477.70
1	Brooks Creek	Mouth	intersection with CR 74 S	upstream of where CR 74 S used to cross creek	Pennville, Section 1, T23N, R12E	657241.87 x 4481848 m
2	Mud Creek	Bales Ditch	intersection with CR 200 N	under bridge	Pennville, Section 2, T23N, R12E	656512.47 x 4480858.26 m
3	Mud Creek	Mud Creek	intersection with SR 26	under bridge	Pennville, Section 10, T23N, R12E	655131.83 x 4479165.02 m
4	Brooks Creek	Brooks One	intersection with CR 150 N	upstream of bridge	Pennville, Section 12, T23N, R12E	657671.27 x 4480076.77 m
5	Harris Creek	Harris Creek	intersection with SR 1	upstream of bridge	Pennville, Section 24, T23N, R12E	656955.32 x 4476690.29 m
6	Brooks Creek	Brooks Two	intersection with CR 50 S	downstream of bridge	Pennville, Section 24, T23N, R12E	657346.07 x 4475986.94 m
7	Smith-Hartman Ditch	Smith-Hartman	south of CR 200 S	7 m upstream from confluence with Brooks Creek	Pennville, Section 36, T23N, R12E	657814.97 x 4474371.85 m
8	Phillips Run	Phillips Run	west of CR 800 W	16 m upstream from confluence	Pennville, Section 36, T23N, R12E	659335.96 x 4473694.56 m

				with Brooks Creek		
9	Brooks Creek	Stephens Run	north of CR 300 S	20 m downstream from mouth of Stephens Run	Blaine, Section 32, T23N, R12E	660524.15 x 4473095.41 m
10	Brooks Creek	Headwaters	intersection with Mt. Pleasant Road	downstream of bridge	Ridgeville, Section 11, T22N, R13E	666072.77 x 4470698.82 m

* An X indicates that the data was not available.

Water Chemistry

Methods

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacterial parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* using a YSI Model 85 meter. (Alkalinity, temperature, and dissolved oxygen were measured during base flow only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional area of the stream channel was measured, and discharge was calculated by multiplying water velocity by cross-sectional area. The water stage at the reference site was too deep to wade all the way across the channel; therefore, no discharge measurement was made during base flow. The storm flow discharge was estimated by measuring accessible stream depths from both sides of the stream and estimating cross-sectional area based on available measurements. In addition, water samples were collected from just below the water surface using a cup sampler and tested for:

- pH
- alkalinity (during base flow only)
- turbidity
- total Kjeldahl nitrogen (TKN)
- ammonia-nitrogen (NH_3)
- nitrate-nitrogen (NO_3^-)
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- total suspended solids (TSS)

Following collection, samples were stored in an ice chest until analysis either in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory (for the base flow samples) or the A&L Great Lakes Laboratory (for the storm flow samples). All sampling techniques and laboratory analytical methods were performed in accordance with procedures in Standard Methods for the Examination of Water and Wastewater, 19th Edition (APHA, 1995). Appendix 5 provides copies of the laboratory reports for the samples.

The comprehensive evaluation of stream chemistry requires collecting data on the different water quality parameters listed above. A brief description of the various parameters follows:

Temperature The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits for Indiana streams. Temperatures during the month of May should not exceed 80°F (23.7°C) by more than 3°F (1.7°C). June temperatures should not exceed 90°F (32.2°C). The Code also states that "the maximum temperature rise at any time or place…shall not exceed 5°F (2.8°C) in streams…". Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds.

Dissolved Oxygen (D.O.) D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 parts per million (ppm) of D.O. Cold-water fish such as trout generally require higher concentrations of D.O. than warm water fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 6 mg/l for cold water fish. D.O. enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1995). During low discharge, conductivity is higher than during storm water runoff because the water moves more slowly across or through ion-containing soils and substrates during base flow. Carbonates and other charges particles dissolve into the slow-moving water, thereby increasing conductivity measurements.

pH The pH of stream water describes the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of air is nitrogen gas. This nitrogen can diffuse into water where it can be "fixed", or converted, by blue-green algae for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate (NO_3) **–** Nitrate is dissolved nitrogen that is converted to ammonia by algae. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters. Nitrogen applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams that support modified warmwater habitat (MWH) was 1.6 mg/l. Modified warmwater habitat was defined as: aquatic life use assigned to streams that have irretrievable, extensive, man-induced modifications that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate concentrations exceeding 10 mg/l in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia (NH_3) **–** Ammonia is dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found where dissolved oxygen is lacking. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between approximately 0.13 and 0.22 mg/l.

Organic Nitrogen (Org N) **–** Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles, and there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) **–** SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/l (or 30 μg/l) can cause algal blooms. The Ohio EPA

(1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/l.

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended and dissolved in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. Although the State of Indiana sets no standard for TSS, total dissolved solids should not exceed 750 mg/l. In general, TSS >80 mg/l have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria**
E. coli is one member of a group of bacteria that comprise the Fecal Coliform Bacteria and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 col/100 ml in any one sample within a 30-day period. A study conducted by students at IUSPEA in the spring of 2000 found average fecal coliform levels of <200 colonies/100 ml in unglaciated, gravel-bottom creeks in the Stephen's Creek Watershed in Monroe County, Indiana (Klumpp et al., 2000). In general, fecal coliform bacteria have a die-off rate of 90% in 3-5 days (Gerba and McLeod, 1992). However, Sherer et al. (1992) found that fecal coliform bacteria lived an average of 17 days longer when incubated with sediment. Additionally, benthic sediments can harbor significantly higher concentrations of bacteria than the overlying water, and disturbance of the sediment can result in contamination of the water column.

Samples were collected on two dates: one following a storm event and the other during normal or "base flow" conditions. A base flow sampling provides an understanding of typical conditions in the streams. Following storm events, the increased water flow overland results in increased erosion of soil and nutrients from the land. Thus, stream concentrations of nutrients and sediment are higher following storm events. In essence, storm sampling presents a "worst case" picture of the watershed pollutant loading. The storm event samples were taken on June 6, 2000 following a storm that dumped almost three inches of rain on the watershed during a period of 48 hours, constituting a one-year storm event. Due to the magnitude of the storm event, the soils were likely saturated at the time of sampling. The base flow samples were collected on May 30 and 31, 2000 following a period of little precipitation. It is important to note that even though these results provide insight into the characteristics of the streams at the time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions.

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). *Mass loading* (in units of kg/day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is the most important when considering the effects of these materials downstream.

Results

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling are presented in Table 41. Stream discharges measured during base and storm flow conditions are shown in Figure 19. The base flow conditions were likely higher than summer time low flows based on examination of the channels and water elevations at the time of the base flow sampling. Based on weather data, the stream levels were still receding from an earlier storm event. As expected, sites 1, 3, and 6 on the mainstem of Brooks Creek had higher discharges than the tributary streams. Storm flow at the reference site was 20 times greater than that of any other stream.

TABLE 41. Physical characteristics of Brooks Creek Watershed streams sampled on May 30, 2000 and June 6, 2000.

Site	Date	Timing	Flow (cfs)	Temp. °C	D. O. (mg/l)	Cond. (umhos)	pH	Alk. (mg/l)	Turbidty (NTU)
Reference Site	05/30/00	Base	**	18.0	8.5	543	8.2	140	32.0
Reference Site	06/06/00	Storm	590	*	*	440	7.7	*	133.0
SITE 1 Brooks Cr	05/30/00	Base	16.9	19.8	8.3	578	8.1	172	35.5
SITE 1- Brooks Cr	06/06/00	Storm	20.4	*	*	610	8.1	*	53.0
SITE 2- Mud Cr	05/31/00	Base	3.6	16.5	8.5	588	8.1	194	10.0
SITE 2- Mud Cr	06/06/00	Storm	7.3	*	*	630	7.9	*	50.0
SITE 3- Mud Cr	05/31/00	Base	1.9	17.3	9.1	566	8.1	193	11.0
SITE 3- Mud Cr	06/06/00	Storm	2.5	*	*	510	7.9	*	61.0
SITE 4- Brooks Cr	05/31/00	Base	7.3	18.7	9.6	604	8.1	183	24.0
SITE 4- Brooks Cr	06/06/00	Storm	19.6	*	*	690	8.3	*	48.0
SITE 5- Harris Cr	05/31/00	Base	0.7	17.0	8.8	502	8.1	154	28.5
SITE 5- Harris Cr	06/06/00	Storm	1.9	*	*	520	7.7	*	60.0
SITE 6- Brooks Cr	05/31/00	Base	5.2	18.0	8.0	611	8.0	190	17.0

SITE 6-Brooks Cr	06/06/00	Storm	27.2	*	*	600	7.9	*	47.0
SITE 7-Smith-Hartman	05/31/00	Base	0.8	18.6	8.8	549	8.1	162	26.0
SITE 7-Smith-Hartman	06/06/00	Storm	3.1	*	*	570	8.0	*	57.0
SITE 8-Phillips R	05/31/00	Base	0.3	20.4	7.9	577	8.2	189	30.0
SITE 8-Phillips R	06/06/00	Storm	0.97	*	*	520	8.0	*	78.0
SITE 9-Brooks Cr	05/31/00	Base	1.8	20.7	9.2	693	8.4	204	8.5
SITE 9-Brooks Cr	06/06/00	Storm	7.6	*	*	550	7.9	*	34.0
SITE 10-Brooks Cr	05/31/00	Base	0.4	22.7	12.6	561	8.4	198	8.0
SITE 10-Brooks Cr	06/06/00	Storm	0.95	*	*	590	7.9	*	11.0

* Data not available
** Discharge too high to measure

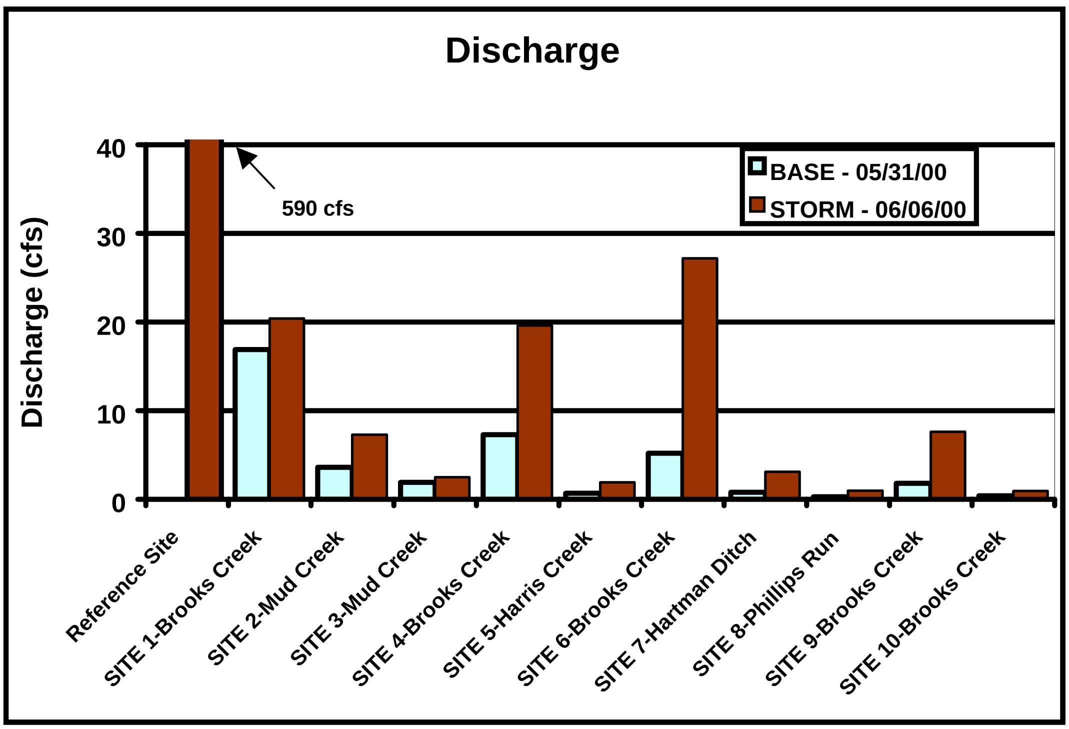


FIGURE 19. Discharge or flow measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

During base flow conditions, temperatures in the creeks varied from 16.5°C at Site 2 to 22.7°C at Site 10. Those creeks with cooler temperatures likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher temperatures in streams located higher in the watershed (Sites 8, 9, and 10) are likely due to their small size, lack of riparian shading, and lower proportion of groundwater inputs.

Dissolved oxygen (DO) concentrations varied from 7.9 to 12.6 ppm. Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to consider DO saturation values. This refers to the amount of oxygen dissolved in water compared to the maximum possible when water is saturated with oxygen. The saturation value of water at 18°C is 9.5 ppm or mg/l. Stream dissolved oxygen concentrations that are less than this value suggest that: a) decomposition processes within the streams consume oxygen more quickly than it can be replaced by diffusion from the atmosphere, and b) flow in the streams is not turbulent enough to entrain sufficient oxygen. Results from these sites indicate that oxygen was sufficient. DO in all streams exceeded the Indiana state minimum standard of 6 mg/l indicating that oxygen was sufficient.

Conductivity in Brooks Creek Watershed streams ranged from 502-693 umhos during base flow and from 440-690 umhos during storm water runoff. In general during low discharge, conductivity was higher than during the storm sampling. High flows tend to dilute charge-bearing ions and allow little time for ion dissolution into the water from the soils.

Values of pH were well within the range of 6-9 units established by the Indiana Administrative Code. pH levels during base flow were generally greater (8.0-8.4) than levels measured during storm flow conditions (7.7-8.3). During low water periods, stream water has a longer amount of time to accrue buffering compounds from alkaline soils.

Alkalinity measurements taken during base flow conditions indicate that Brooks Creek Watershed streams are well-buffered. The reference site actually had the lowest alkalinity at 140 mg/l and would be the least capable of buffering or resisting changes in pH.

Turbidity was greatest during storm flow conditions for all sites. At base flow conditions, Site 10 had the lowest turbidity of 8.0 NTU while Site 1 had the greatest turbidity of 35.5 NTU. During periods of high flow, turbidity is greater due to increased overland flow carrying suspended sediments with it into the creeks. Interestingly, the reference site was almost twice as turbid as any other study stream during runoff. Phillips Run (Site 8), Mud Creek (Site 2), and Harris Creek (Site 5) also became notably more turbid during runoff.

Chemical and Bacterial Concentrations

Chemical and bacterial concentration data for Brooks Creek Watershed streams are listed by site in Table 42. Figures 20-26 present concentration information graphically.

TABLE 42. Chemical and bacterial characteristics of Brooks Creek Watershed streams sampled on May 30, 2000 and June 6, 2000.

Site	Date	Timing	NO_3^- (mg/l)	NH_3 (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	E. coli (col/100ml)
Reference	05/30/00	Base	0.02	0.081	0.605	0.104	0.171	42.0	*

Site									
Reference Site	06/06/00	Storm	18.70	BDL	3.000	BDL	BDL	208.0	4800
SITE 1- Brooks Cr	05/30/00	Base	9.18	0.076	0.926	0.082	0.082	46.8	*
SITE 1- Brooks Cr	06/06/00	Storm	7.50	BDL	9.000	BDL	BDL	54.0	2400
SITE 2- Mud Cr	05/31/00	Base	7.58	0.098	0.322	0.044	0.087	16.0	*
SITE 2- Mud Cr	06/06/00	Storm	6.70	0.100	2.000	BDL	BDL	38.0	6600
SITE 3- Mud Cr	05/31/00	Base	7.29	0.064	0.708	0.051	0.091	15.8	*
SITE 3- Mud Cr	06/06/00	Storm	7.90	0.140	2.000	BDL	BDL	44.0	2600
SITE 4- Brooks Cr	05/31/00	Base	8.24	0.065	1.113	0.082	0.121	28.3	*
SITE 4- Brooks Cr	06/06/00	Storm	8.00	BDL	2.000	BDL	BDL	57.0	2200
SITE 5- Harris Cr	05/31/00	Base	6.73	0.084	1.641	0.059	0.124	29.6	*
SITE 5- Harris Cr	06/06/00	Storm	11.20	0.150	2.000	0.120	0.400	50.0	1400
SITE 6- Brooks Cr	05/31/00	Base	7.75	0.095	1.033	0.076	0.076	22.8	*
SITE 6- Brooks Cr	06/06/00	Storm	8.30	0.110	3.000	BDL	0.300	35.0	1600
SITE 7- Smith-Hartman	05/31/00	Base	8.90	0.084	0.861	0.141	0.247	23.2	*
SITE 7- Smith-Hartman	06/06/00	Storm	11.20	0.260	2.000	0.180	0.350	50.0	2800
SITE 8- Phillips R	05/31/00	Base	10.29	0.065	0.746	0.057	0.144	32.2	*
SITE 8- Phillips R	06/06/00	Storm	12.00	BDL	2.000	BDL	BDL	56.0	6200
SITE 9- Brooks Cr	05/31/00	Base	3.16	0.086	0.779	0.038	0.131	4579.7	*
SITE 9- Brooks Cr	06/06/00	Storm	5.90	BDL	1.000	BDL	BDL	34.0	4000
SITE 10- Brooks Cr	05/31/00	Base	1.56	0.046	0.733	0.019	0.091	10.0	*
SITE 10- Brooks Cr	06/06/00	Storm	3.90	BDL	2.000	BDL	BDL	12.0	1000

* = Data not available
BDL = Below Detection Limits

Nitrate concentrations in the Brooks Creek watershed streams are illustrated in Figure 20. Nitrate concentration at every site during storm water runoff exceeded 1.6 mg/l, the median nitrate concentration of wadeable streams found by the Ohio EPA to support modified warmwater habitat (MWH). During base flow conditions every site except the reference site and Brooks Creek (Site 10) exceeded 1.6 mg/l. Because nitrate is very mobile in soils, an additional concern is groundwater and well water contamination. Four sites exceeded the IAC standard of 10 mg/l during storm flow; one site exceeded the standard during base flow.

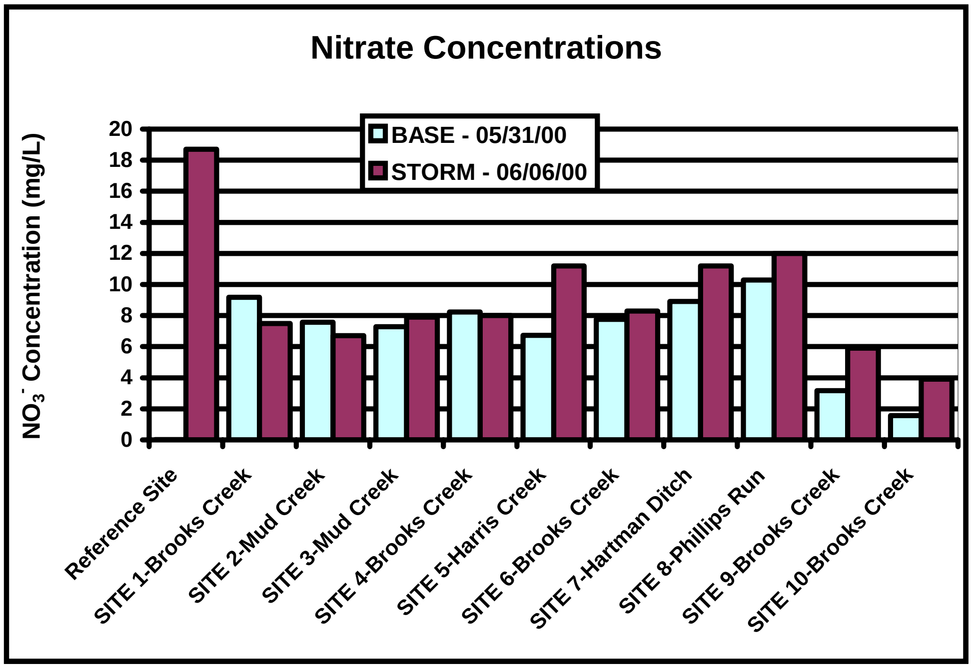


FIGURE 20. Nitrate concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

Ammonia concentrations (Figure 21) generally fell within the range (0.13-0.22 mg/l) set by the IAC as determined by *in situ* temperatures and pH values. During storm flows, Smith-Hartman Ditch (Site 7) exceeded the top end of the range at 0.26 mg/l, while both Harris Creek (Site 5) and Mud Creek (Site 3) exceeded the low end of the range at 0.15 and 0.14 mg/l, respectively. At the very least, these concentrations are near the minimum water quality standard for aquatic life. High rates of runoff during storms can wash ammonia from farm fields and livestock areas into the streams.

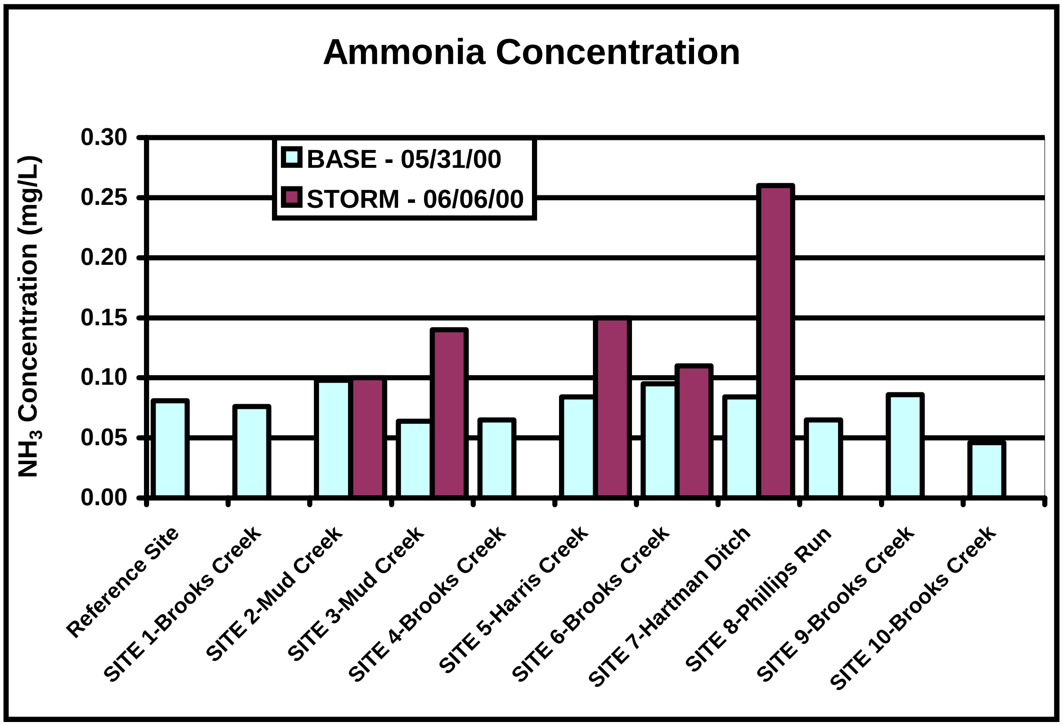


FIGURE 21. Ammonia concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

Total Kjeldahl nitrogen (TKN) concentrations detected in streams were also elevated during storm flows (Figure 22). Concentrations measured on the mainstem of Brooks Creek near its mouth (Site 1) were highest, reflecting watershed inputs from all tributaries.

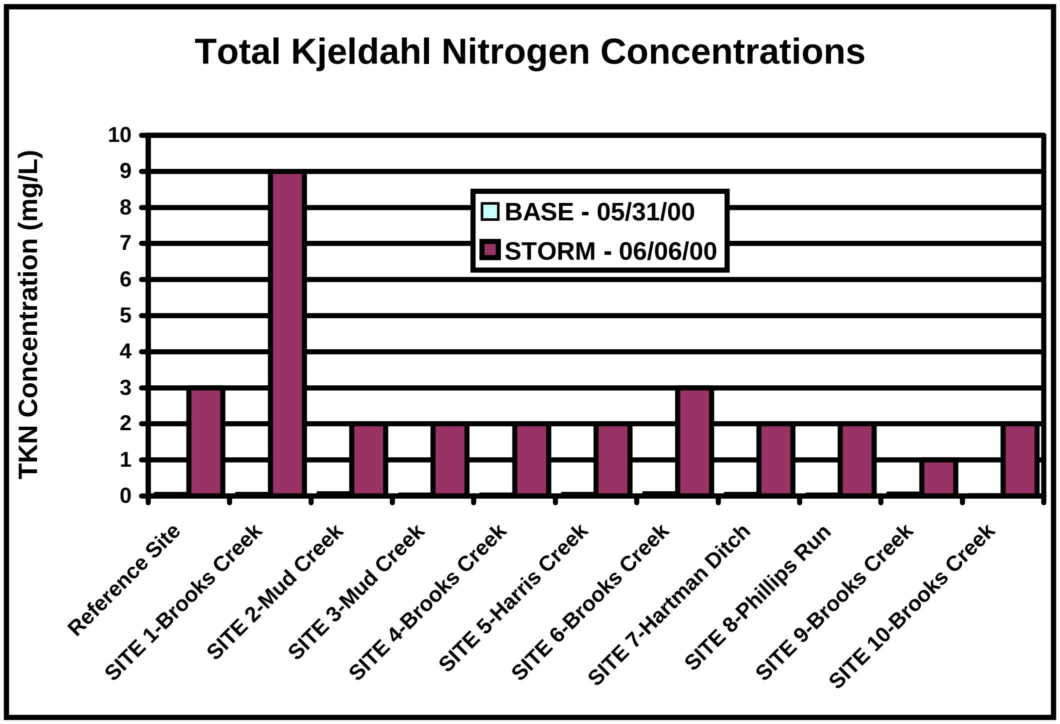


FIGURE 22. Total Kjeldahl nitrogen (TKN) concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

All detected concentrations of soluble reactive phosphorus (SRP) exceeded minimum levels that prevent overproductivity in aquatic systems (Figure 23). Soluble phosphorous comprised 21-100% of the total phosphorus measured at the sampling sites. At Mud Creek (Site 2), Hartman Ditch (Site 7), Mud Creek (Site 2), and Brooks Creek (Sites 1,4, and 6), SRP was >50% of the measured TP, suggesting that a large fraction of the phosphorus coming off the land and into surface drainageways was soluble rather than particulate. Many storm flow SRP and TP samples were below detection limits (BDL in Table 42). Based on base flow concentrations and storm flow samples that were measurable, it is believed that a laboratory error or the high laboratory detection limit of 0.10 mg/l resulted in the BDL assignments.

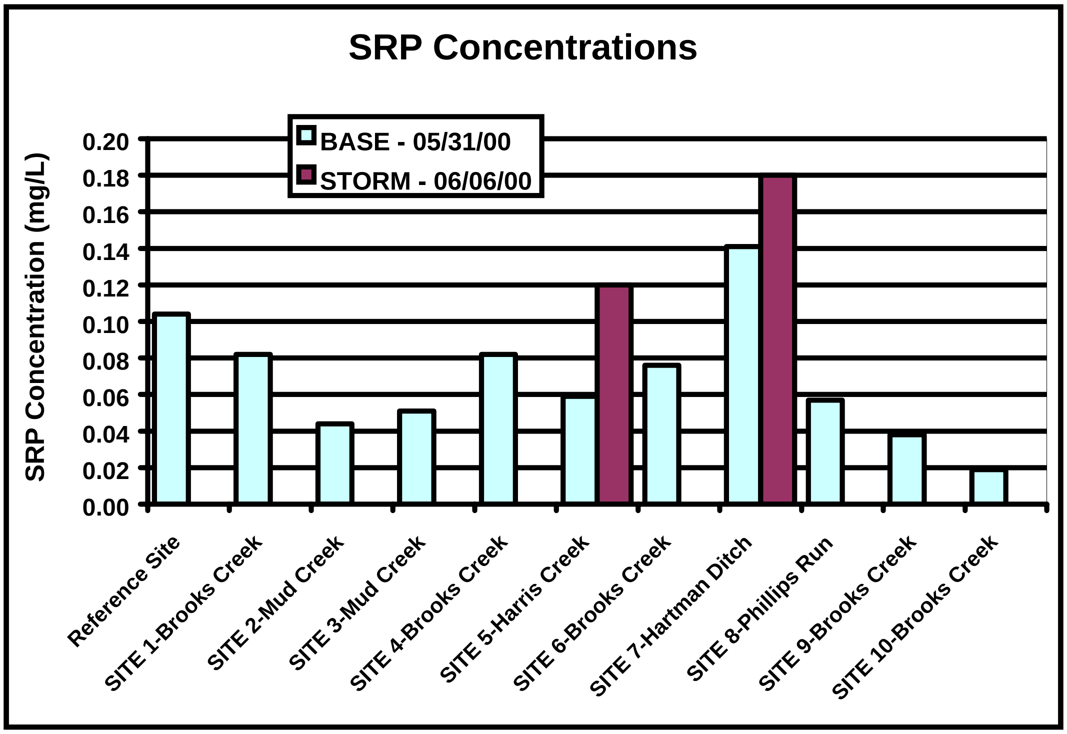


FIGURE 23. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

Total phosphorus concentrations (Figure 24) were also greater than minimum levels known to stimulate algal production. During base flow, none of the sites exceeded the 0.28 mg/l level acceptable for modified warmwater habitat (MWH, Ohio EPA, 1999). However, storm flow concentrations at Harris Creek (Site 5), Brooks Creek (Site 6), and Smith-Hartman Ditch (Site 7) were greater than the acceptable median level.

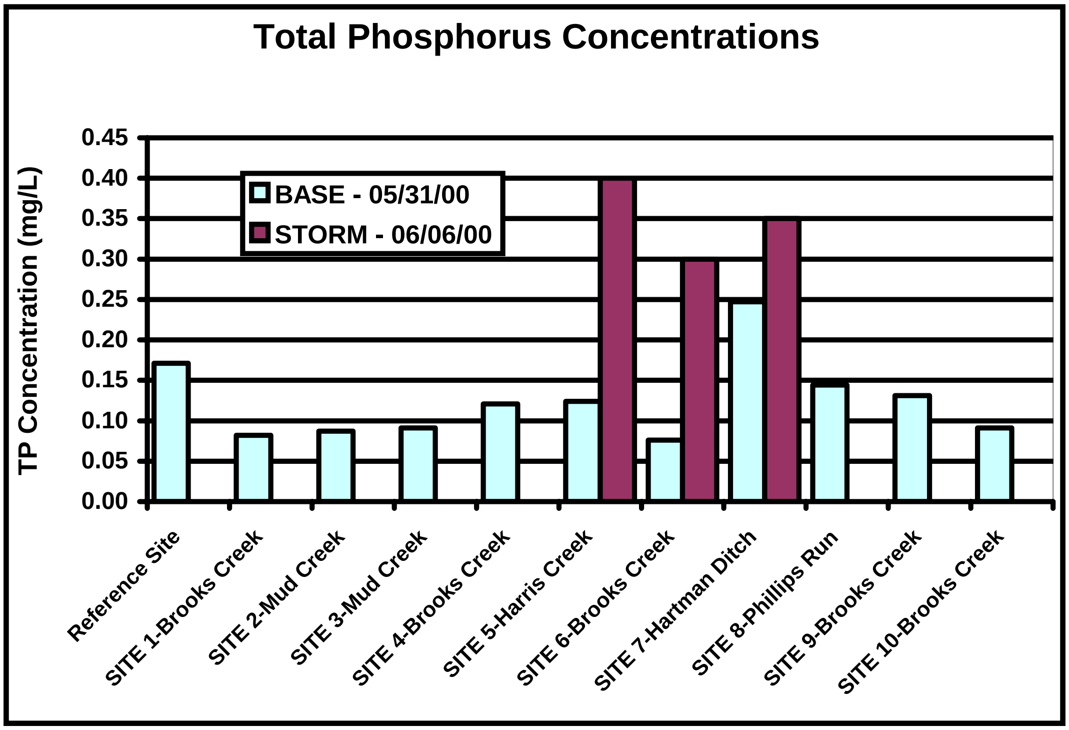


FIGURE 24. Total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

Concentrations of total suspended solids (TSS) were greater during storm flow conditions than during base flow conditions for every site except for Site 9 (Figure 25). The inordinately high TSS concentration for Site 9 during base flow conditions was probably due to the sampling team having to walk downstream to the sampling site in the creek itself since there was no other safe access. This stirred up a significant amount of fine sediments that did not clear readily. In general even during storm flow, concentrations of TSS were below the 80 mg/l level known to be deleterious to aquatic life.

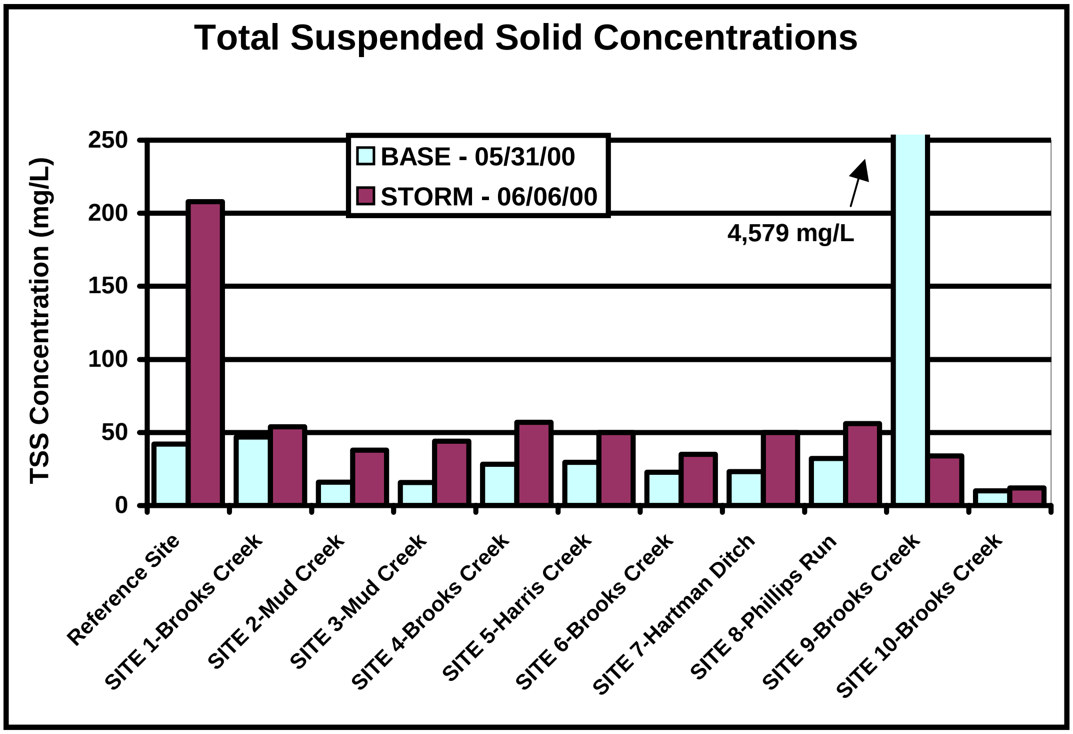


FIGURE 25. Total suspended solid (TSS) concentration measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

All storm water samples for *E. coli* violated the Indiana state standard for recreational waterbodies of 235 col/100ml (Figure 26). *E. coli* concentrations ranged from 1000 col/100ml at Brooks Creek (Site 10) to 6600 col/100ml at Mud Creek (Site 2). Based on this analysis, humans and pets may contract disease from water in the creeks following storm events and should not come into contact with it without appropriate protection.

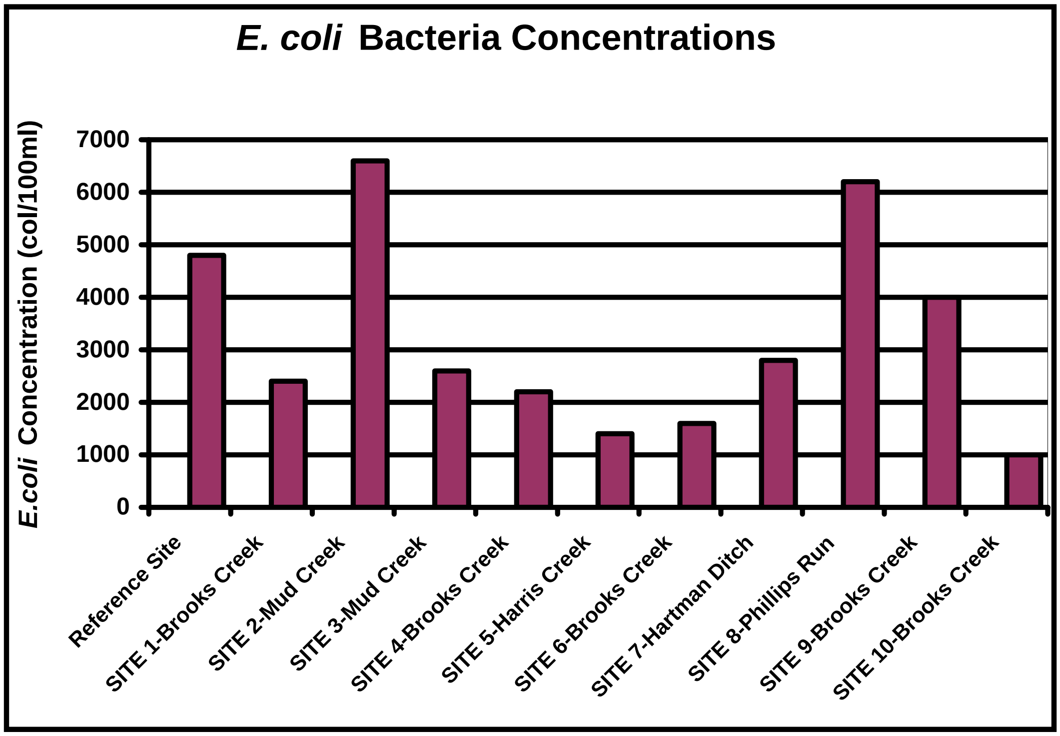


FIGURE 26. *E. coli* bacteria concentration measurements during the storm flow sampling of Brooks Creek Watershed streams.

Sediment and Chemical Loading

Nutrient and sediment loading from streams in the Brooks Creek Watershed was mostly governed by flow rate (i.e., streams with higher rates of flow also contributed higher nutrient and sediment loads). Nitrate loading was completely governed by flow rate (Figure 27). Smith-Hartman Ditch contributed significantly to ammonia loading despite having a relatively small flow (Figure 28). Total nitrogen loading from the watershed as a whole (as measured at Site 1 near the mouth of Brooks Creek) was significantly increased during storm flow conditions (Figure 29). Due to laboratory error and/or detection limits, SRP and TP storm flow loading rates were difficult to analyze; however, Smith-Hartman Ditch contributed disproportionately higher SRP loads relative to its flow rate (Figures 30 and 31). Sediment loading was also completely driven by flow rate, suggesting that no single reach was contributing disproportionate amounts of sediment (Figure 32). Although sediment loading rates were high (ranging from 10 to 2734 kg/day or 22 to 6015 lbs/day), no single reach had a detectibly higher soil loading rate or a soil erosion problem of greater magnitude than any other. (The measurement of sediment at Site 9 during base flow was excluded from this calculation due to the artificially high measurement.)

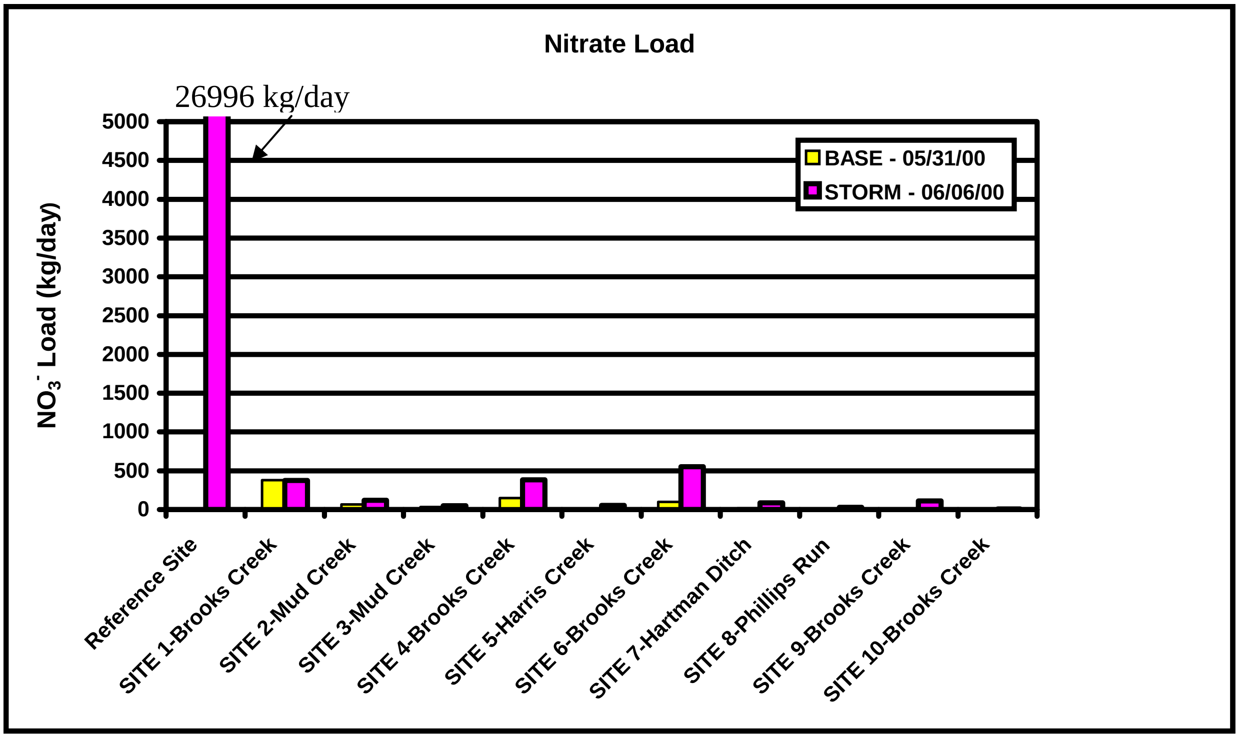


FIGURE 27. Nitrate loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

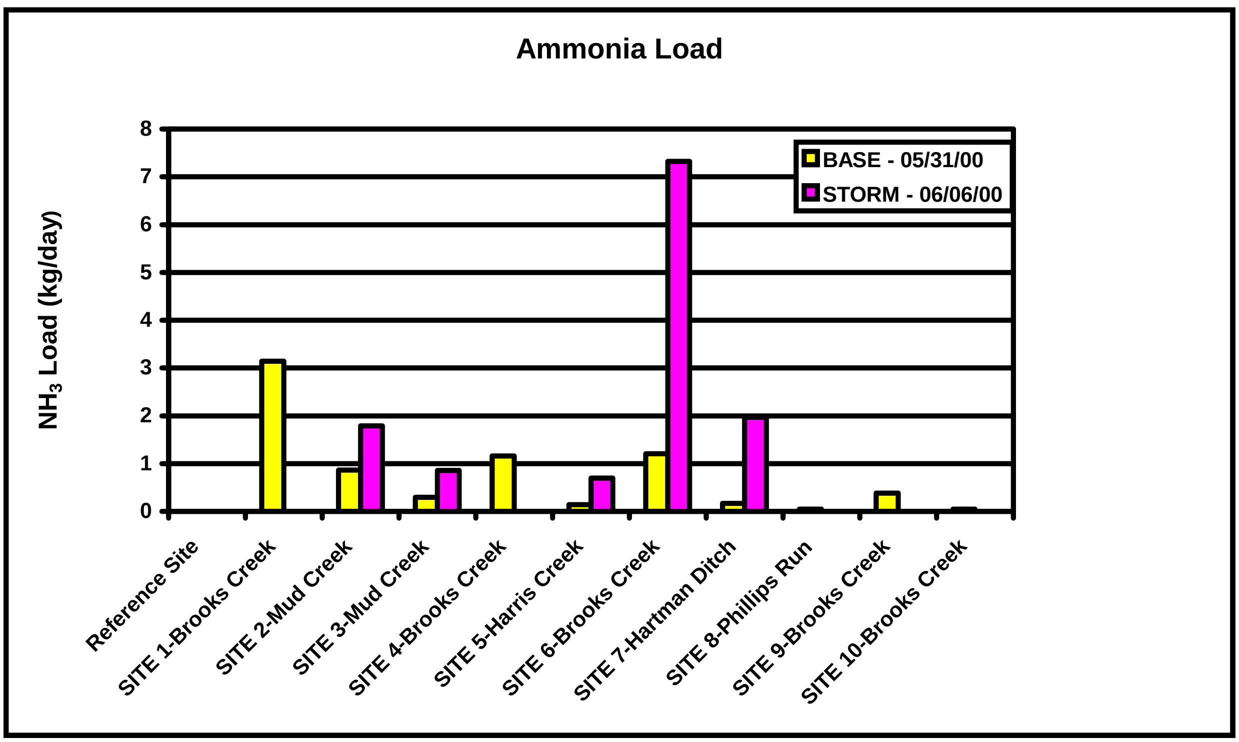


FIGURE 28. Ammonia loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

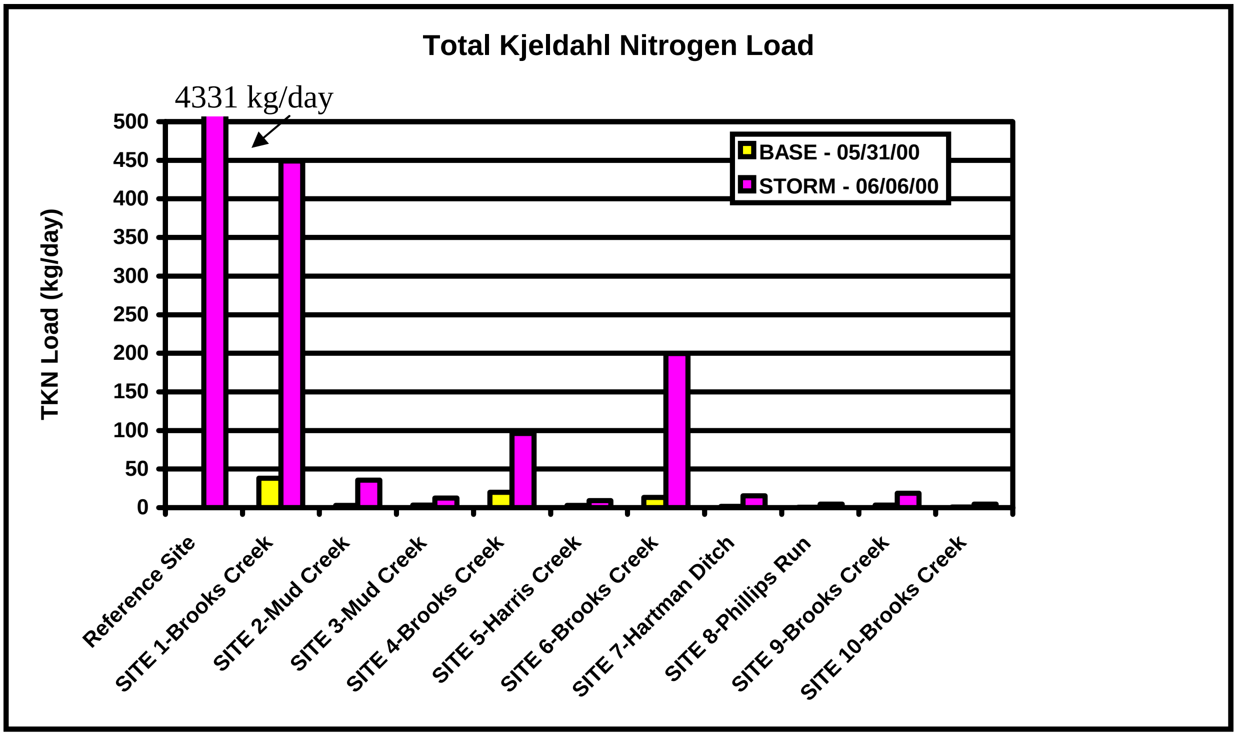


FIGURE 29. Total Kjeldahl nitrogen (TKN) loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

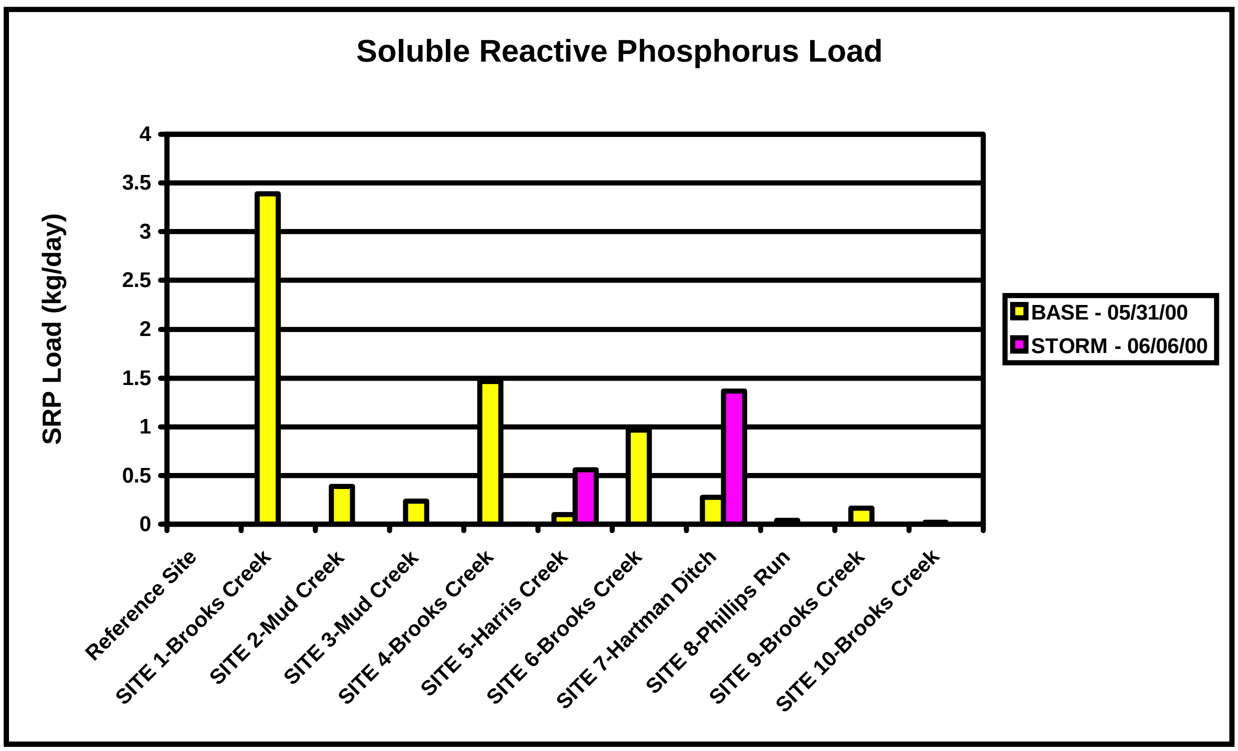


FIGURE 30. Soluble reactive phosphorus (SRP) loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

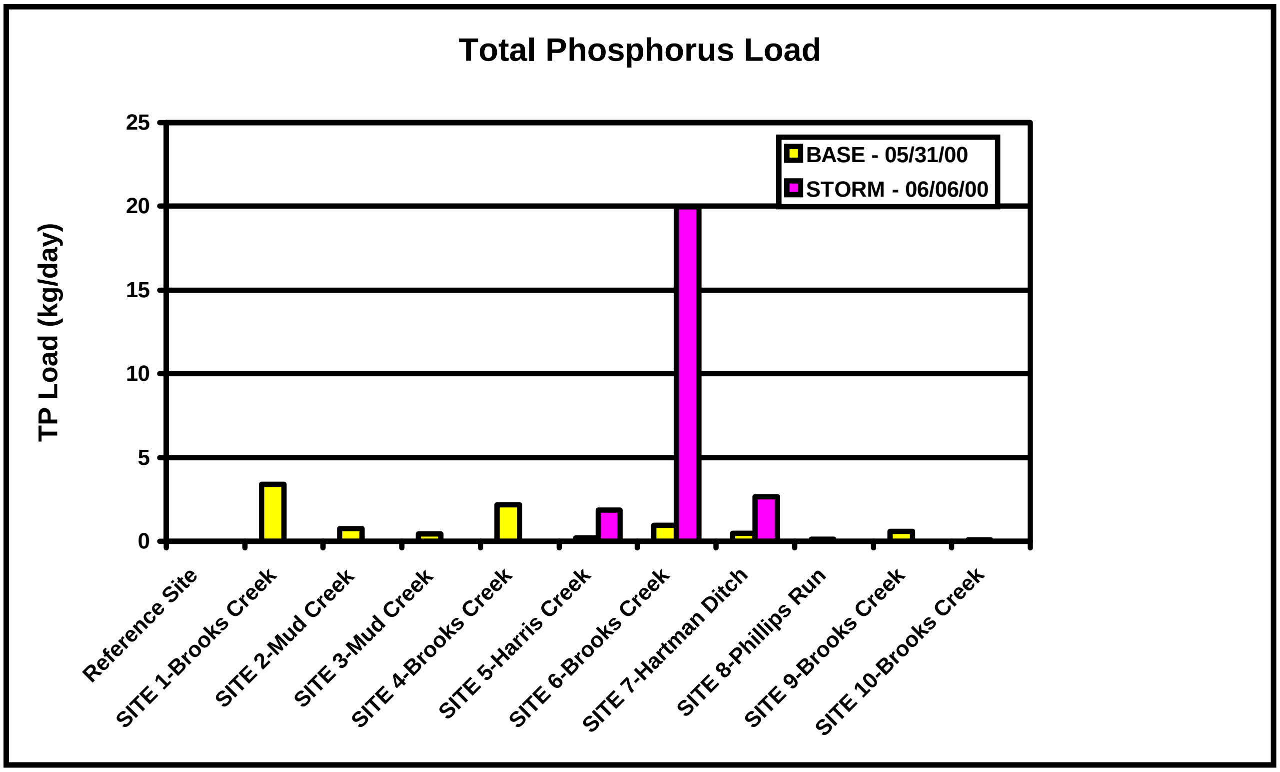


FIGURE 31. Total phosphorus (TP) loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

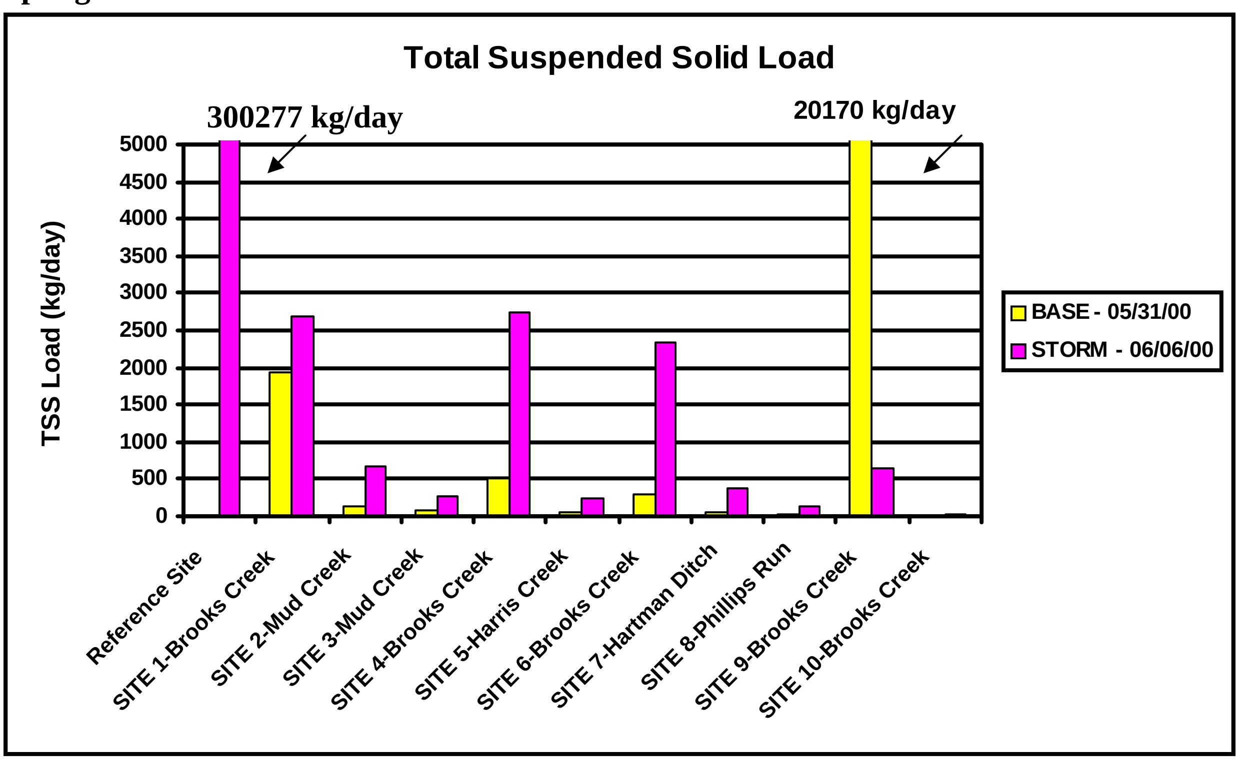


FIGURE 32. Total suspended solid (TSS) loading measurements during base flow and storm flow sampling of Brooks Creek Watershed streams.

Discussion

In an effort to normalize the sediment, nutrient, and bacteria loading rates, the rates were divided by subwatershed size above each sampling site. Sampling sites in certain subwatersheds received loading from adjacent subwatersheds. In these cases, loads from adjacent subwatersheds were subtracted from the subwatershed of consideration. For example, loading measured at Site 4 at the mouth of the Brooks One Subwatershed includes loading from the Harris Creek Subwatershed (Site 5) and loading from the Brooks Two Subwatershed (Site 6). During analysis, if loading from Sites 5 and 6 are subtracted from Site 4, then the difference is the load contributed by the area drained for Site 4 (which is the Brooks One Subwatershed). Because what is coming into the subwatershed can be greater than what is leaving it, negative areal loading rates are possible. Table 43 shows sample sites representing the respective subwatersheds. Due to limited resources for sampling, Bales Ditch and Crooked Creek Subwatersheds could not be separated for purposes of this analysis. Stephens Run and Jeffs Run could not be separated either. Sampling Site 1 was taken to represent Brooks Creek Watershed as a whole. Table 44 shows the results of this analysis.

TABLE 43. Sampling sites representing Brooks Creek Watershed and its subwatersheds.

Watershed/Subwatershed	Sampling Site(s)
Brooks Creek Watershed	1
Bales Ditch and Crooked Creek Subwatersheds	= 2-3
Mud Creek Subwatershed	3
Brooks One Subwatershed	= 4-(5-6)
Harris Creek Subwatershed	5
Brooks Two Subwatershed	= 6-(7-8-9)
Smith-Hartman Ditch Subwatershed	7
Phillips Run Subwatershed	8
Stephens Run and Jeffs Run Subwatershed	= 9-10
Headwaters	10

TABLE 44. Areal loading of TSS, TP, and *E. coli* by subwatershed based on the base flow and storm flow samplings.

Watershed/Subwatershed	Watershed Size	Timing	TSS Load (kg/ha/yr)	TP Load (kg/ha/yr)	*E. coli* Load (millions of col/ha/yr)
Brooks Creek Watershed	27440 ac (11109 ha)	base	63.6	0.11	X
Brooks Creek Watershed	27440 ac (11109 ha)	storm	88.6	BDL	3936
Bales Ditch and Crooked Creek Subwatershed	2751 ac (1114 ha)	base	22.3	0.11	X
Bales Ditch and Crooked Creek Subwatershed	2751 ac (1114 ha)	storm	134.0	BDL	33421
Mud Creek Subwatershed	3718 ac (1505 ha)	base	17.8	1.19	X

Mud Creek Subwatershed	3718 ac (1505 ha)	storm	65.3	BDL	3857
Brooks One Subwatershed	2668 ac (1080 ha)	base	55.5	0.34	X
Brooks One Subwatershed	2668 ac (1080 ha)	storm	58.5	BDL	-2530
Harris Creek Subwatershed	1643 ac (665 ha)	base	27.8	0.12	X
Harris Creek Subwatershed	1643 ac (665 ha)	storm	127.3	1.04	3571
Brooks Two Subwatershed	1345 ac (545 ha)	base	NC	-0.13	X
Brooks Two Subwatershed	1345 ac (545 ha)	storm	858.8	BDL	-2788
Smith-Hartman Ditch Subwatershed	2185 ac (885 ha)	base	18.7	0.21	X
Smith-Hartman Ditch Subwatershed	2185 ac (885 ha)	storm	156.4	1.11	8763
Phillips Run Subwatershed	2106 ac (853 ha)	base	10.1	0.04	X
Phillips Run Subwatershed	2106 ac (853 ha)	storm	56.9	BDL	6299
Stephens Run and Jeffs Run Subwatershed	7135 ac (2889 ha)	base	NC	0.06	X
Stephens Run and Jeffs Run Subwatershed	7135 ac (2889 ha)	storm	76.3	BDL	9105
Headwaters Subwatershed	2540 ac (1028 ha)	base	3.5	0.03	X
Headwaters Subwatershed	2540 ac (1028 ha)	storm	9.9	BDL	825

* NC = Not Calculated due to unnaturally elevated TSS measured at Site 9.
* BDL = Below Detection Limit
* X = Sample not collected

The Brooks Two Subwatershed contributed almost five time more sediment per unit area than any other subwatershed during storm water runoff. The Smith-Hartman Ditch, Bales Ditch and Crooked Creek together, and Harris Creek each loaded over 100 kg/ha/yr (89 lbs/ac/yr) during storm flows. Sediment loading was significantly lower during low flow conditions. Per acre of subwatershed area, Mud Creek and Smith-Hartman Ditch contributed the greatest load of total phosphorus. The Brooks Two Subwatershed was the only depositional area or net sink area for total phosphorus having a negative areal loading rate. *E. coli* loading was worst from the Bales Ditch/Crooked Creek Subwatershed which loaded as much as 33 billion col/ha/yr during storm water runoff. Areal bacterial loading was also elevated in the Stephens Run/Jells Run, Smith-Hartman Ditch, and Phillips Run Subwatersheds. *E. coli* bacteria loads demonstrated a net loss per unit area within the Brooks One and Brooks Two Subwatersheds. This net loss is probably due to death or deposition without substantial bacterial input within these reaches.

Summary

In general, the physical and chemical characteristics of these streams indicate a high degree of degradation. The nutrient concentrations were much higher than median nutrient concentration observed in modified Ohio streams. Additionally, multiple parameters violated Indiana state standards for both human and aquatic biota health as established by the Indiana Administrative Code. The Smith-Hartman Ditch Subwatershed is of special concern due to its high loading rate of dissolved nutrients (NH_3 and SRP) relative to its low flow rate. Sediment loading rates were found to be quite high (22-6015 lbs/day), but no subwatershed was contributing detectibly higher sediment loads based on flow rates. While some reaches per unit area acted as net sinks for phosphorus and bacterial loads, others delivered high loads of sediment, nutrients, and bacteria. The Brooks Two Subwatershed produced the most TP, and the Bales Ditch/Crooked Creek Susbwatershed loaded the most *E. coli* per unit of watershed area. Again the Smith-Hartman Ditch merits concern because it ranked in the top three subwatersheds for elevated TSS, TP, and *E. coli* loading per unit area.

Macroinvertebrates and Habitat

Macroinvertebrate Sampling Methods

Macroinvertebrate samples from each of the 10 sites and the reference site were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition reflects water quality, and research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on May 30 and 31, 2000 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes, and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al. 1984, Ferraro and Cole 1995, Marchant 1995, Bowman and Bailey 1997, Waite et al. 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). A higher value on the HBI scale indicates greater impairment.

In addition to the HBI, macroinvertebrate results were analyzed by applying the IDEM mIBI (IDEM, 1996). mIBI scores allow comparison with data compiled by IDEM for wadeable riffle-pool streams in Indiana. Table 45 lists the ten scoring metrics with classification scores of 0-8. The mean of the ten metrics is the mIBI score. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired, scores of 4-6 indicate the site is slightly impaired, and scores of 6-8 indicate that the site is non-impaired. IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected in Indiana. The data was lognormally distributed for each of the ten metrics. Each of the ten metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Because a different sampling methodology was used in this study, only six of the ten metrics were used for the mIBI calculation: family-level HBI, number of taxa, percent dominant taxa, EPT Index, EPT count to total number of individuals, and EPT count to chironomid count.

TABLE 45. Benthic macroinvertebrate scoring metrics and classification scores used by IDEM in evaluation of riffle-pool streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
		CLASSIFICATION SCORE			
	0	**2**	**4**	**6**	**8**
Family Level HBI	□5.63	5.62- 5.06	5.05-4.55	4.54-4.09	□4.08
Number of Taxa	□7	8-10	11-14	15-17	□18
Number of Individuals	□79	129-80	212-130	349-213	□350
Percent Dominant Taxa	□61.6	61.5-43.9	43.8-31.2	31.1-22.2	□ 22.1
EPT Index	□2	3	4-5	6-7	□8
EPT Count	□19	20-42	43-91	92-194	□195
EPT Count To Total Number of Individuals	□0.13	0.14-0.29	0.30-0.46	0.47-0.68	□0.69
EPT Count To Chironomid Count	□0.88	0.89-2.55	2.56-5.70	5.71-11.65	□11.66
Chironomid Count	□147	146-55	54-20	19-7	□6
Total Number of Individuals To	□29	30-71	72-171	172-409	□410

Number of Squares Sorted					

Where 0-2 = Severely Impaired; 2-4 = Moderately Impaired; 4-6 = Slightly Impaired; 6-8 = Nonimpaired

Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. An example of the QHEI data sheet is given in Appendix 6.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1995).

Results

mIBI and QHEI scores for each sampling site and the reference site are given in Tables 46 and 47. Detailed mIBI results are included in Appendix 7. The mIBI scores ranged from 0.0 to 6.0. All QHEI scores except for Site 8 within the Brooks Creek Watershed fell below 60, the level conducive to existence of warmwater faunas (Ohio EPA, 1999). QHEI scores were not statistically correlated with mIBI scores, meaning that degraded habitat as measured by the QHEI did not necessarily correlate with a depauperate benthic community as measured by the mIBI. Brief descriptions and representative photos of habitat quality for the reference site and each of the 10 sampling follows.

TABLE 46. Classification scores and mIBI score for sampling sites within the Brooks Creek Watershed and reference site as sampled May 30-31, 2000.

	Reference Site	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**
HBI	0	6	8	6	0	6	6	0	6	6	8
No. Taxa (family)	4	2	6	6	2	0	4	0	0	0	8
% Dominant Taxa	4	2	4	4	0	4	2	0	6	6	8
EPT Index	2	2	4	4	2	2	0	0	2	2	4
EPT Count/Total Count	2	8	4	6	0	2	6	0	6	6	2
EPT Abun./Chir. Abun.	0	8	8	8	0	8	6	0	8	8	6
mIBI Score	**2.0**	**4.7**	**5.7**	**5.7**	**0.7**	**3.7**	**4.0**	**0.0**	**4.7**	**4.7**	**6.0**

TABLE 47. QHEI Scores for the Brooks Creek Watershed sampling sites and reference site as sampled May 30-31, 2000.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Reference Site	14	19	12	5.5	4	4	4	**62.5**
SITE 1-Brooks Creek	14	10	12	9	4	4	4	**57**
SITE 2-Mud Creek	5	6	7	5	0	0	4	**27**
SITE 3-Mud Creek	12	3	8	5	4	2	4	**38**
SITE 4-Brooks Creek	10	2	5	7.5	0	0	4	**28.5**
SITE 5-Harris Creek	2	1	6	4	0	0	4	**17**
SITE 6-Brooks Creek	9	7	9	4	0	0	4	**33**
SITE 7-Smith-Hart Ditch	11	10	16	9	0	0	4	**50**
SITE 8-Phillips Run	14	10	17	9	5	2	4	**61**
SITE 9-Brooks Creek	13	4	8	5	4	1	4	**39**
SITE 10-Brooks Creek	3	6	8	4	4	2	4	**31**

Reference Site – Eightmile Creek. The substrate type at this site was 90% sand. Moderate bank erosion was present. The immediate streamside was unvegetated, but higher along the banks the primary vegetation was trees (Figure 33). The banks were steeply sloping with an average height of 16.5 ft (5 m). The Reference Site scored 62.5 of 100 total possible points on the Qualitative Habitat Evaluation Index (QHEI). The QHEI pool score was 4 of 12 and the riffle score was 4 of 8, indicating that pool-riffle development was poor.

FIGURE 33. Reference site sampling location on Eightmile Creek.

Site 1 – Brooks Creek. The substrate type at this site was 95% gravel and 5% cobble. There was a semblance of pool-riffle development. Embeddedness was moderate. The average height of the banks was 10 ft (3 m). Moderate bank erosion was present. Banks were vegetated predominately by trees and low growing woodland plants. Overhanging vegetation, root wads, and woody debris provided in-stream habitat (Figure 34). Site 1 scored 57 of 100 total possible QHEI points.

FIGURE 34. Site 1 sampling location on Brooks Creek near its mouth.

Site 2 – Mud Creek. The substrate type at this site was 30% sand, 30% silt, and 30% clay. The average height of the banks was 6.5 ft (2 m). There was little or no visible bank erosion. Banks were vegetated predominately by trees and shrubs (Figure 35). Overhanging vegetation, logs/woody debris, and shallows provided additional in-stream habitat. Site 2 scored 27 of 100 total possible points on the QHEI. The QHEI cover score was only 6 of 20, indicating that in-stream cover was nearly absent. The QHEI substrate score of only 5 of 20, indicates that the substrate was of poor quality. Pool-riffle development was absent with QHEI pool and riffle scores of 0.

FIGURE 35. Site 2 sampling location on Mud Creek.

Site 3 – Mud Creek. The substrate type at this site was 60% sand, 10% silt, and 30% gravel. There was minimal pool-riffle development. Banks were stabilized by shrubby vegetation and had an average height of 5 ft (1.5 m). There was little or no bank erosion. Banks were vegetated predominately by grasses (Figure 36). Overhanging vegetation and shallows provided additional in-stream habitat. Site 3 scored 38 of 100 total possible points on the QHEI. Because in-stream cover was nearly absent, the QHEI cover score was only 3 of 20.

FIGURE 36. Site 3 sampling location on Mud Creek.

Site 4 – Brooks Creek. The substrate type at this site was 80% silt, 10% sand, and 10% clay. Brooks Creek was unconfined in this reach. Silt deposition had formed bars creating a "braided" stream channel. Upper banks were stabilized by trees and woody vegetation and had an average height of 6.5 ft (2 m). There was little or no bank erosion. Banks were vegetated predominately by herbaceous species (Figure 37). Canopy renovation/removal has eliminated riparian zones in the immediate vicinity. Remnant logs/woody debris provided limited in-stream cover. Site 2 scored 28.5 of 100 total possible points on the QHEI. The QHEI cover score was only 2 of 20, which indicates that in-stream cover was nearly absent. Pool and riffle scores of 0 indicate the absence of pool-riffle habitat.

FIGURE 37. Site 4 sampling location on Brooks Creek.

Site 5 – Harris Creek. The substrate type at this site was 100% rip-rap. There was no embeddedness. The average height of the banks was 1.5 ft (0.5 m). There was little or no bank erosion. Banks were vegetated by non-native pasture grasses (Figure 38). Open pasture and row crop border the edge of the rip-rapped stream. Site 5 scored 17 of 100 total possible points on the QHEI. The QHEI cover score was only 1 of 20, which indicates that in-stream cover was nearly absent. The QHEI substrate score was only 2 of 20, which indicates that the substrate was of poor quality. Little pool-riffle development was evident.

FIGURE 38. Site 5 sampling location on Harris Creek.

Site 6 – Brooks Creek. The substrate type at this site was 90% sand and was extensively embedded. The average height of the banks was 6.5 ft (2 m). There was little or no bank erosion. Banks were vegetated predominately by herbaceous and woody vegetation 39). Overhanging vegetation, aquatic macrophytes, woody debris, and shallows provided in-stream habitat. Site 6 scored 33 of 100 total possible points on the QHEI. Pool-riffle development was absent.

FIGURE 39. Site 6 sampling location on Brooks Creek.

Site 7 – Smith-Hartman Ditch. The substrate type at this site was 90% sand. The average height of the banks was 5 ft (1.5 m). There was little or no bank erosion. Banks were not vegetated in the immediate vicinity of the streamside, but upper banks were vegetated predominately by trees (Figure 40). Overhanging vegetation and shallows provided minimal in-stream habitat. Site 7 scored 50 of 100 total possible points on the QHEI. Pool and riffle scores were also poor.

FIGURE 40. Site 7 sampling location on Smith-Hartman Ditch.

Site 8 – Phillips Run. The substrate type at this site was 90% sand. The average height of the banks was 1.5 ft (0.5 m). There was moderate bank erosion. Banks were vegetated predominately by trees (Figure 41). Overhanging vegetation, logs/woody debris, and shallows provided in-stream habitat. A moderately developed pool-riffle sequence provided additional habitat. Site 8 scored 61 of 100 total possible points on the QHEI. This was the highest QHEI score assigned to any stream in the Brooks Creek Watershed.

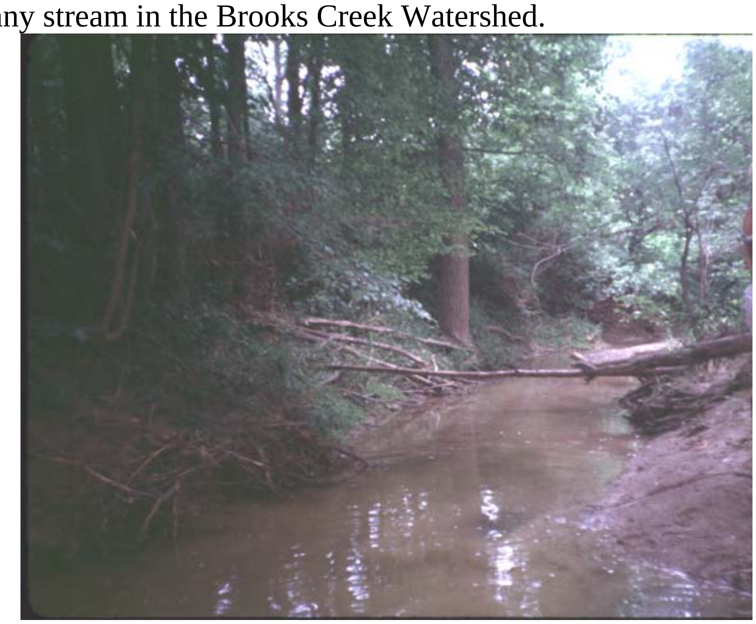


FIGURE 41. Site 8 sampling location on Phillips Run.

Site 9 – Brooks Creek. The substrate type at this site was 90% sand. The average height of the banks was 8 ft (2.5 m). There was little or no bank erosion. Streamside vegetation consisted of non-native pasture grasses and aquatic macrophytes; upper banks were vegetated predominately by shrubs and trees (Figure 42). Moderately developed pool-riffle sequences, aquatic macrophytes, and woody debris provide in-stream vegetation. Site 9 scored 39 of 100 total possible points on the QHEI. With a QHEI cover score of only 4 of 20, in-stream cover was nearly absent.

FIGURE 42. Site 9 sampling location on Brooks Creek.

Site 10 – Brooks Creek. The substrate type at this site was 50% sand, 30% gravel, and 20% silt. The average height of the banks was 8 ft (2.5 m). There was little or no bank erosion. Banks were vegetated predominately by shrubs and herbaceous species (Figure 43). Overhanging vegetation, aquatic macrophytes, and shallows provide in-stream habitat. Site 10 scored 31 of 100 total possible points on the QHEI. The QHEI cover score of only 6 of 20 indicates that in-stream cover was nearly absent. Substrate quality also scored poorly.

FIGURE 43. Site 10 sampling location on Brooks Creek.

Discussion

Because most of the stream reaches surveyed had been channelized in the past, there was little evidence of pool and riffle development, as indicated by the low QHEI scores in these areas. Pool/riffle habitats provide a diversity of habitat conditions that attract a diversity of biotic organisms. The predominant substrate in the streambeds was silt, which provides only limited habitat value. Gravel and cobble substrates provide a diversity of attachment sites that attract many different macroinvertebrates and fish. Work by the drainage board to keep the channel and its banks free of obstructions discourages overhead vegetative cover and lowers the QHEI score.

The overall habitat degradation components which impair conditions for aquatic life within the Brooks Creek Watershed are:

- Siltation/Substrate embeddedness: excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic invertebrates and fish.
- Channel alterations: ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in the stream.
- Poor pool/riffle development: deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load.
- Poor in-stream cover: in-stream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, in-stream cover also is related to certain chemical characteristics like temperature and dissolved oxygen.

The following site-by-site discussion focuses on each site individually offering analysis of the mIBI and QHEI.

<u>*Site 1 – Brooks Creek.*</u> The overall habitat quality at Site 1 was moderate, receiving one of the highest QHEI scores (57) in the Brooks Creek Watershed. However, the most influential parameter that lowered the QHEI score was the substrate component. Substrate at Site 1 was characterized by moderate siltation and moderate embeddedness. Adjacent riparian buffer habitat provided substantial cover and shading for macroinvertebrate taxa. This wooded wetland area promoted improved water quality and therefore, supported an only slightly impaired macroinvertebrate community (mIBI=4.7). Even though sediment loads were elevated at this site, *Hydropsychidae*, a moderately tolerant Tricopteran, dominated the macroinvertebrate community indicating that habitat conditions were still conducive for adaptable fauna. This is further supported by the presence of one species of low tolerance (Appendix 7, Table A-7.3). Site 1 demonstrated signs of habitat recovery and improvement based on the 1991 historical data (Tables 20 and 21). The QHEI score improved from 45 to 57. In particular, the substrate, riparian zone, instream cover, and riffle development improved in habitat quality. The only component that showed further degradation was pool development. The improved mIBI score also supports these habitat enhancements. The 1991 mIBI score of 2.4 indicated that the stream was barely registering as a “moderately” impaired stream. For comparison, Site 1 was scored as a slightly impaired stream during this study. The macroinvertebrate assemblage present at Site 1 was less tolerant than that sampled in 1991, signifying enhanced water habitat quality. Even

though only the two samples from 1991 and 2000 are available and even though the QHEI was still below 60, signs of habitat and biological progression are evident.

<u>Site 2 – Mud Creek.</u> Heavy siltation and excessive embeddedness characterized Site 2. This siltation along with recent channel alterations of canopy removal and bank shaping decreased the QHEI score to 27. In spite of the degraded QHEI score, the segment received a higher "slightly impaired" mIBI score of 5.7. Four main factors contributed to this relatively high score:

- 10% Fine Particulate Organic Matter (FPOM) present within stream reach
- 30% Coarse Particulate Organic Matter (CPOM) present within stream reach
- Periphyton presence
- High macroinvertebrate diversity

Nutrient and sediment loading from the agricultural row crops that were directly adjacent to the stream negatively impacted this site. The riparian habitat had been moderately altered, however the food availability and shelter opportunities within available FPOM and CPOM inflated the mIBI. Site 2 was also one of only two sites within the watershed where periphyton (attached algae) as a form of autotrophic production was present. Periphyton provides food and habitat for many macroinvertebrate species, and its presence is also associated with increased invertebrate species richness.

<u>Site 3 – Mud Creek.</u> As expected, siltation and embeddness also characterized Site 3. The amount of sediment was less than at Site 2 further downstream. Surrounding land use was also predominated by row crop, but this site was slightly buffered by meager riparian vegetation, which served to filter out some agricultural runoff. Even though the riparian vegetation provided bank stability, in-stream stability was very low, decreasing the QHEI score to 38. Lack of periphyton growth limited available resources for aquatic insects, but some macrophytic vegetation increased habitat availability and served to anchor the otherwise unstable substrate.

<u>Site 4 – Brooks Creek.</u> The low QHEI score (28.5) at Site 4 was due to heavy siltation and excessive embeddness, partnered with extremely unstable substrate. Alterations in channel morphology (particularly recent channelization and canopy removal) had hindered and/or perpetuated the lack of pool or riffle development. The poor QHEI score was mirrored in a poor mIBI score, a relationship that is expected. Site 4 had the second lowest mIBI, which was probably directly correlated with an overall lack of aquatic habitat. This site was characterized by a tolerant macroinvertebrate assemblage supported by degraded habitat. The site was dominated by *Chironomidae*, a pollution tolerant Dipteran (Appendix 7, Table A-7.9). The depressed mIBI score of 0.7 was the result of a lack of macroinvertebrate diversity along with the dominance of tolerant species. In conclusion, Site 4 lacked any instream habitat and demonstrated no pool or riffle development. Watershed land use exacerbated the degradation by providing excessive nutrient and sediment loading. These deteriorated conditions led to a low mIBI coupled with a low QHEI.

<u>Site 5 – Harris Creek.</u> The QHEI score at Site 5 was lower than at any other site in the Brooks Creek Watershed. The main factors causing impairment included:

- 100% artificial rip-rap substrate
- No pool or riffle development
- No in-stream cover

- Recent channelization, including canopy removal and bank shaping
- No riparian buffer strip

Site 5 also had a moderately impaired mIBI score of 3.7. The stream was found to be only moderately impaired because the rip-rap material did provide some permanent stability and habitat for macroinvertebrates. Additionally, the presence of periphyton contributed to macroinvertebrate species richness by providing habitat for more diverse trophic guilds.

Site 6 - Brooks Creek. Sediment from the watershed inundated the stream reach at Site 6, causing heavy siltation and extensive embeddness. Sand dominated the remaining substrate type, making the substrate very unstable for habitat development and establishment. Along with poor substrate, there was no pool or riffle development and very little riparian cover. Substrate and poor stream morphology decreased the QHEI score to 33. The availability of some in-stream cover, such as logs, woody debris, and overhanging vegetation allowed for a moderately to slightly impaired macroinvertebrate community (mIBI=4.0). Some macrophytic growth provided a small degree of stabilization and cover.

Site 7 - Smith-Hartman Ditch. Even though Site 7 scored a moderately poor QHEI of 50, the ditch received an mIBI score of zero. Three main factors influenced both the QHEI and mIBI scores in this reach:

- Moderate siltation and embeddedness
- Unstable substrate
- No pools or riffles

Riparian buffer areas did border the stream providing shading; however, no rootwads, logs, or woody debris were present within the stream reach to provide in-stream cover. A mere three organisms were found within the stream reach. The lack of any substantial macroinvertebrate community was probably due to a complete lack of any macroinvertebrate habitat:

- No pools or riffles
- Unstable homogenous substrate
- No autotrophs (plants or other organisms capable of producing their own food)– impedes trophic level development
- No CPOM – impedes trophic level development
- No in-stream cover

Site 7 provided no shelter and no food resources for aquatic biota.

Site 8 - Phillips Run. Site 8 scored the highest QHEI of 61, just below the reference site, which scored 62.5. Substrate types were diverse, and stream morphology had been less altered than that of most other sites. Pool and riffle complexes were also established. These characteristics fostered a macroinvertebrate assemblage of slight impairment. Even though the riparian vegetation is predominantly woody wetland, this stream reach experiences excessive nutrient loading from the surrounding agriculture. High nutrient loading and immature stream habitat establishment supported fairly pollution and disturbance-tolerant individuals. Due to shading from the riparian vegetation, autotrophs were not present in the stream, reducing possible shelter and food sources.

Site 9 - Brooks Creek. Site 9 received a low QHEI score but the highest mIBI score of the Brooks Creek Watershed. Site 9 was surrounded entirely by agricultural row crop with little remaining natural riparian vegetation. Along with absent riparian cover and nearly absent in-stream cover, unstable sandy substrate characterized Site 9. These factors decreased the QHEI score to 39. Somewhat at odds with the QHEI, the macroinvertebrate assemblage was resilient and showed high diversity, with an mIBI score of 6.0 (slightly impaired/nonimpaired). This relatively high score was probably due to macrophyte (rooted aquatic vegetation) establishment that served to stabilize substrate and provide habitat for macroinvertebrates.

Site 10 – Brooks Creek. Site 10, along with Site 9, obtained the highest mIBI score; however, watershed activities have degraded the habitat, resulting in a QHEI of only 31. Heavy siltation and excessive embeddedness from adjacent agriculture dominated the stream habitat. The QHEI also suffered due to predominantly artificial substrate and unstable sand. Site 10 is located upstream of all other sites in the headwaters of the Brooks Creek Watershed. Such streams are generally governed by material originating from the watershed rather than material produced in the stream (Cummins et al., 1980). Site 10 partially fits the characterization of headwater streams because CPOM was relatively scarce (10%); however, surrounding land use had destroyed the natural ecosystem structure of headwater streams. Despite the riparian alterations, the macroinvertebrate community of Site 10 demonstrated some resilience because the stream reach included:

- 5% rooted macrophytes
- 10% CPOM
- FPOM presence

These factors provide valuable shelter and food for biota. Siltation and embeddedness due to watershed land use have eliminated available habitat for periphyton.

Summary

All sampling sites within the Brooks Creek Watershed demonstrate some degree of impairment as measured by the QHEI and the mIBI. The QHEI and mIBI were not statistically correlated, indicating that some other factor(s) besides habitat quality was playing a role in macroinvertebrate community structure. Habitat impairment was mostly due to siltation/substrate embeddedness, channel alterations, poor pool and riffle development, and poor in-stream cover. Habitat quality was most degraded on Harris Creek (Site 5) and Mud Creek (Site 2) as measured by the QHEI. mIBI scores for Brooks Creek at Site 4 and Smith-Hartman Ditch (Site 7) were alarmingly low. The macroinvertebrate community at Site 4 was of low richness and composed predominantly of highly tolerant taxa. Only three organisms were sampled in the 50 minutes of collection effort on the Smith-Hartman Ditch. This depauperate assemblage is probably the result of poor water and habitat quality.

In summary, the impaired conditions documented within Brooks Creek Watershed streams are a result of both in-stream and watershed-level practices. Drainage, water quality, and biological health could be dramatically improved by incorporation of land management practices and conservation advocacy within the watershed and riparian zones.

Relationships Among Chemical, Biological, and Habitat Characteristics

Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI Score vs mIBI Score
- QHEI Substrate vs. mIBI Score
- QHEI Channel vs. mIBI Score
- QHEI Riparian vs. mIBI Score
- QHEI Cover vs. mIBI Score
- QHEI Score vs. TSS (mg/L)
- QHEI Riparian vs. HBI
- QHEI vs. HBI
- QHEI Cover vs. HBI
- mIBI vs. NO_3 (mg/L)
- mIBI vs. Total Nitrogen (mg/L)
- mIBI vs. TSS (mg/L)
- HBI vs. NO_3 (mg/L)
- HBI vs. TSS (mg/L)

One possible explanation for this lack of correlation is that these creeks are, in general, highly modified, somewhat artificial drainage ditches, and consequently might not reflect natural relationships among parameters of water quality, habitat quality, and biological health.

Total phosphorus and soluble reactive phosphorus concentrations were statistically related ($p<0.05$) to macroinvertebrate community quality within the Brooks Creek Watershed (Figures 44 and 45). The Ohio EPA documented an inverse relationship between phosphorus concentrations and biological community performance in numerous streams in Ohio (Ohio EPA, 1999). Excessive soil erosion and particulate and dissolved nutrient inputs have been shown to be associated with agricultural land use and stream degradation (Allen, 1995). Unlike their well-organized, diverse, and trophically dynamic high quality aquatic counterparts, degraded systems do not sequester available nutrients. This “viscous cycle” leads to even higher nutrient concentrations and more greatly impaired water quality.

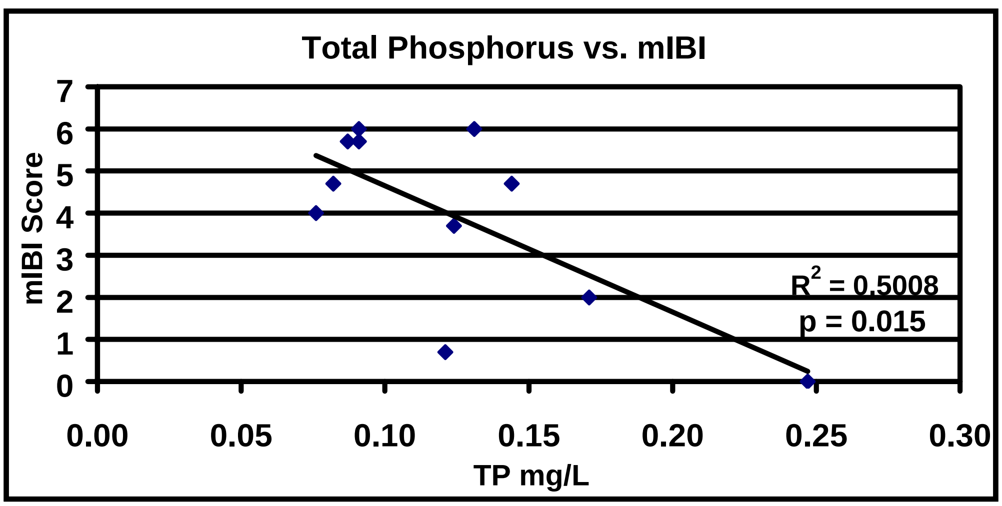


FIGURE 44. Statistically significant relationship between total phosphorus (TP) and mIBI scores measured for the Brooks Creek Watershed sites.

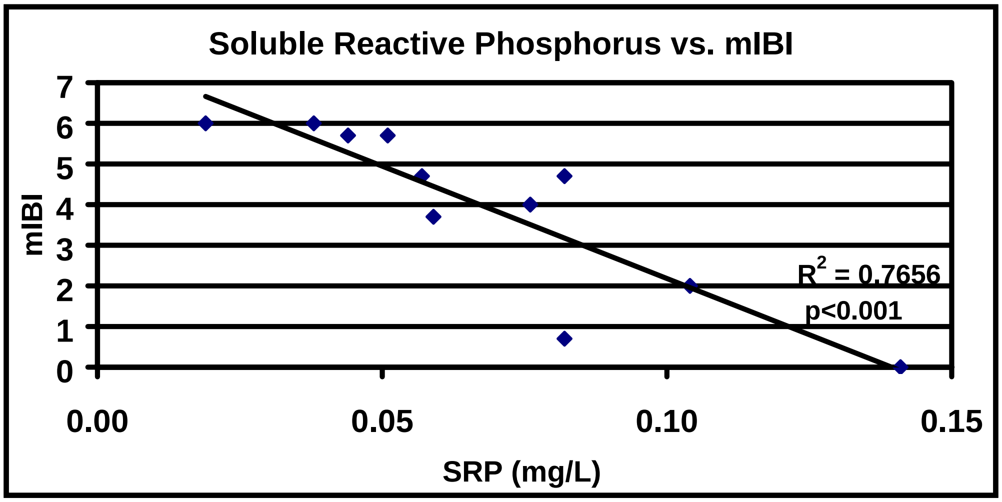


FIGURE 45. Statistically significant relationship between soluble reactive phosphorus (SRP) and mIBI scores measured for the Brooks Creek Watershed sites.

LOADING MODEL

Phosphorus export from each of the Brooks Creek Subwatersheds was roughly estimated using phosphorus export coefficients (Table 48) after Reckhow et al. (1980). The export coefficients are based on land use and the fact that certain land uses result in more nutrient loading to streams than others. For instance, general agricultural land use with a coefficient of 0.5 results in more phosphorus loading than pasture/grassland land use with a coefficient of 0.15. Export coefficients were multiplied by the acreage in each subwatershed to give a phosphorus mass exported per year (kg/yr) by each subwatershed. These numbers were normalized for subwatershed area to give an export estimation of mass per hectare per year (kg/ha/yr).

TABLE 48. Phosphorus export coefficients used to model phosphorus loading in the Brooks Creek Watershed.

Land Cover	P-Export (kg/ha/yr)
Water	0.00
Low Intensity Residential	0.50
High Intensity Residential	0.90
Commercial	0.50
Deciduous Forest	0.10
Evergreen Forest	0.15
Mixed Deciduous/Evergreen Forest	0.10
Pasture/Grassland	0.15
Row Crop	0.50
Woody Wetland	0.10
Herb. Wetland	0.05

It is important to note that this model is very general in nature. For example, not all agricultural row crop land use is best described by a 0.5 export coefficient. Different crop types and different Best Management Practice implementations certainly affect phosphorus transport from the land. Additionally, other factors like soil type and topography are not considered by a model this general in nature.

Land use is fairly homogeneous across the subwatersheds within the Brooks Creek Drainage (See Appendix 1). Agricultural row crop accounted for 71-91% of land use in all subwatersheds. The next two most common land uses were pasture/grassland and deciduous forest. Because land uses were so similar among subwatersheds, subwatershed area tended to drive phosphorus export (i.e., larger subwatersheds like Stephens Run and Jeffs Run exported more phosphorus than smaller subwatersheds). Figure 46 and Table 49 show this result. When normalized for area, the Bales Ditch and Crooked Creek Subwatersheds together dominated phosphorus export (Figure 47). According to the model, the Brooks Two, Mud Creek, and Harris Creek also contributed significant phosphorus loads per hectare. These four areas also contain the highest percentages (81-91%) of agricultural row crop (see Appendix 1).

TABLE 49. Phosphorus export for each subwatershed given in kg/yr and kg/ha/yr.

Subwatershed	Phosphorus Export (kg/yr)	Phosphorus Export (kg/ha/yr)
Bales Ditch and Crooked Creek	516.70	0.46
Mud Creek	651.40	0.43
Harris Creek	285.66	0.43
Smith-Hartman Ditch	360.38	0.41
Phillips Run	332.70	0.39
Stephens Run and Jeffs Run	1131.55	0.39
Headwaters	409.20	0.40
Brooks One	441.70	0.41
Brooks Two	288.12	0.43
Mouth	206.97	0.41

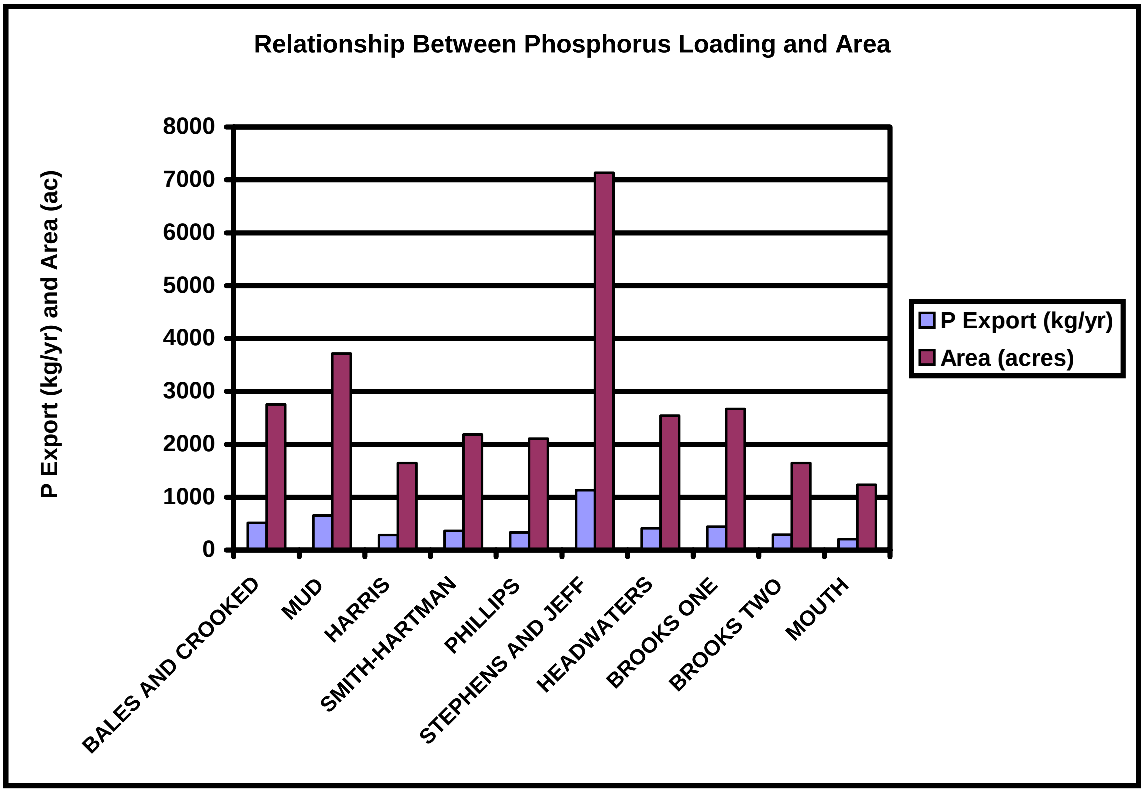


FIGURE 46. Relationship between phosphorus loading and area estimated by the export model.

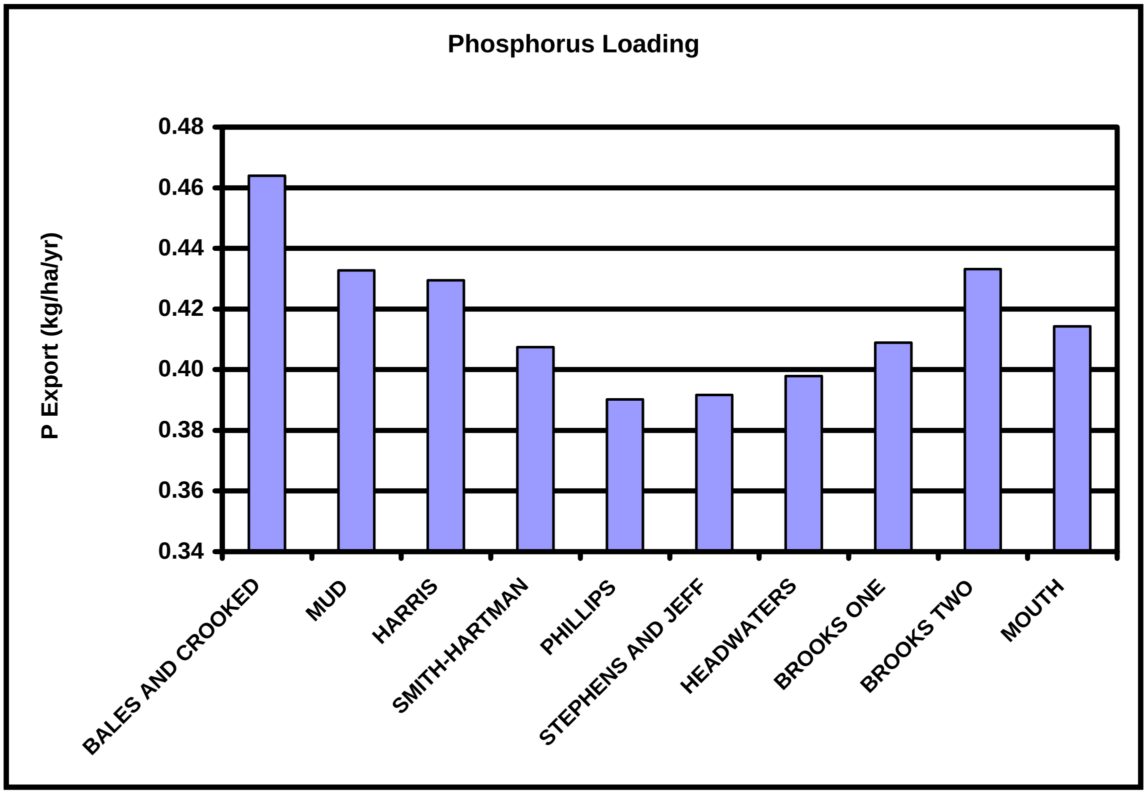


FIGURE 47. Phosphorus loading per unit area as estimated by the export model.

RECOMMENDATIONS

All of the smaller watersheds within the Brooks Creek Watershed could benefit from land treatment and best management strategies as already described in detail in the Watershed Investigation Section. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

These prioritizations and recommendations are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize subwatersheds for future work. The subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the prioritization section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

Prioritization

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Brooks Creek Watershed should be:

1. Crooked Creek Subwatershed
2. Smith-Hartman Ditch Subwatershed
3. Mud Creek Subwatershed
4. Phillips Run Subwatershed
5. Brooks Two Subwatershed
6. Bales Ditch Subwatershed
7. Jeffs Run Subwatershed
8. Brooks One Subwatershed
9. Headwaters Subwatershed
10. Stephens Run Subwatershed
11. Harris Creek Subwatershed

12. Mouth Subwatershed

Crooked Creek is of top priority because a large percentage of its watershed (42%) is classified as highly erodible. Several potential project sites were identified (Figure 16), and three of these project sites are located on HEL. Crooked Creek also contributed significantly to sediment, nutrient, and bacteria loading especially during storm flows.

Smith-Hartman Ditch is also of primary concern due to elevated TSS, TP, and *E. coli* loading per unit area and high loading rates of dissolved nutrients relative to flow rate. While the Smith-Hartman Ditch Subwatershed does contain more HEL than is average for the Brooks Creek Watershed, the mIBI score of 0 is also cause for prioritization and perhaps for further investigation.

Mud Creek is also of high priority due to elevated loading of water quality parameters per unit of watershed and also due to a fairly low percentage of CRP treatment relative to HEL. The windshield survey identified 12 potential project sites, three of which are located on HEL.

All but one of the eight potential identified project sites on Phillips Run is located on HEL. Additionally, the Phillips Run Subwatershed contains the smallest amount of land protection through the CRP than any other subwatershed in the Brooks Creek drainage. Phillips Run should be targeted for future management due to these issues. The Brooks Two Subwatershed is next on the priority list for reasons similar to those already discussed for Phillips Run.

The Bales Ditch Subwatershed loaded high amounts of sediment and bacteria to Brooks Creek. Additionally, the QHEI score was low at Site 2 in the Bales Ditch Subwatershed. Three potential project sites within this subwatershed should be prioritized.

The remaining six subwatersheds are of lower priority because they were generally responsible for lower amounts of pollutant loading and generally already contain more protected land in CRP relative to HEL than the subwatersheds of top priority. Jeffs Run and Stephens Run together do contribute significantly to bacteria loading despite fairly high CRP:HEL ratios. In very general terms, subwatersheds with more HEL protected in CRP do tend to have better water quality.

General Recommendations

1. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowers' opinions of management systems, and to quantify the value to surface and groundwater quality improvement. Use this information to work with interested landowners to formulate individual Resource Management Plans.
2. Implement recommended BMPs and projects discussed for each subwatershed (Tables 26-37) based on subwatershed priority. These projects include: bank stabilization, encouragement of riparian vegetation growth, filter strip and grassed waterway installation, livestock fencing, grade control and other structure installation, stormwater treatment, and creating additional water storage capacity where possible. This work should focus on interested landowners in identified critical areas first.

3. Consider working with the County Drainage Board to develop improved, more sustainable drainage management plans. A sustainable drainage management plan might include maintenance or dredging in only very specific necessary locations instead of cleaning entire reaches, allowing necessity to dictate maintenance instead of budget availability, and education and outreach to help landowners understand the value of intact riparian zones. Specialists like the county surveyor and drainage administrator may have other ideas for a complete and sustainable plan.
4. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches were identified by this study.
5. Consider a project to preserve the small remaining amount of wetlands near the mouth of Griffen Ditch and in a few scattered locations throughout the Somers Creek Watershed. of Brooks Creek. By working with landowners and area schools, the Jay County SWCD could "adopt" these areas for educational activities. Alternatively, the area could be designated or recognized as a conservatory, and landowners could be formally recognized for their conservation efforts.
6. Consider wetland restoration and shallow water pond construction options for reducing flow volumes and velocities. Although in many situations, construction of wetland areas is not feasible due to surrounding land uses and drainage needs, water filtration and storage will affect water quality downstream. It will also reduce bank and channel damage downstream.
7. Advocate CRP enrollment and participation in other programs especially on land of high erosion potential and in high priority subwatersheds. Reach out to landowners who have participated in the past and encourage re-enrollment.
8. Maintain and survey projects after completion. All projects including filter strips and grassed waterways require maintenance to ensure proper function.
9. Invite producers and other landowners out to successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.
10. Work with landowners to fence cattle and other grazing animals away from streams.
11. Encourage all landowners in the watershed to allow natural riparian vegetation growth. Their rooting systems impart many natural benefits to the stream.
12. Work on education and outreach in the watershed. Landowners who are educated about critical environmental areas on their land will be more responsive to projects and programs and will become more involved in protection and conservation of resources.
13. Promote conservation tillage practices especially on HEL tracts and in environmentally sensitive areas. Inform farmers of the benefits of no-till, especially after the 3rd consecutive year of use.
14. Work with the Jay County Purdue Cooperative Extension Agency to promote education on proper nutrient, herbicide, and pesticide management. Promote realistic yield goals instead of optimum yield goals especially on HEL tracts and in environmentally sensitive areas. Promote environmental set-backs in critical areas.
15. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.

16. Reach out to a school or other volunteer group to set up volunteer monitoring within the watershed through the Hoosier Riverwatch Program.
17. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets forth goals for the watershed based on stakeholders' desires, forwards a plan of how to reach the goal, and provides for monitoring of success toward reaching the goal. To be effective, all stakeholders must be included in the plan's development.
18. Work with the highway department and the County Drainage Board to implement best management practices for treatment of storm water runoff from roadways and other impervious surfaces. Figure 17 Site 10 shows a photo taken during the windshield survey where storm water treatment is needed. Storm water from roadways should be routed to detention basins and/or vegetated areas to allow for filtration and settlement of suspended particles. An initial detention basin project could be built for use as a demonstration and education tool.
19. Work with the County Health Department to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. Additionally, the Jay County Health Department maintains a list of soil scientists that conduct on-site soil investigations to characterize soils for septic system citing. If building was necessary on a site where conditions were not suitable for a traditional system, alternative technology could be constructed and the site used as a demonstration and education/outreach tool.
20. Homeowners in the watershed should:
    a) Avoid lawn fertilizing near the stream's edge.
    b) Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c) Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
    d) Avoid mowing up to the stream's edge; allow natural riparian vegetation growth.
    e) Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.
    f) Maintain field drainage tiles and use filter strips around tile risers.
    g) Consider working with the Jay County NRCS to formulate a Resource Management Plan for each individual property.

ADDITIONAL FUNDING SOURCES AND WATERSHED RESOURCES

Funding and other resources are important for the actual implementation of recommended management practices in a watershed. Several cost share and grant programs are available to help offset costs of watershed projects. Additionally, both human and material resources may be available in the watershed.

Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations and/or Soil and Water Conservation Districts (SWCDs) can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a “watershed management activist” it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

This is the program that funded this diagnostic study. LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program’s main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a “watershed land treatment” component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. The watershed land treatment program is highly recommended as a project funding source for the Brooks Creek Watershed.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state’s 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) Watershed Protection Grant

The Watershed Protection Grant program is funded by the EPA and is administered locally by IDEM. These grants provide funding for the reduction and elimination of pollution within a targeted watershed. Priorities for funding include wetland/watershed protection demonstration projects, river corridor and wetland restoration projects, wetland conservation plans, assessment and monitoring plans, and wetland assessment models. The awarded amount can vary by project and there is a required 25% match.

Other Federal Grant Programs

The USDA and EPA award research and project initiation grants through the US National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program

As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices are also eligible for EQIP cost-share.

Farmland Protection Program

The Farmland Protection Program (EPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals EPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species, or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent or within administered conservation areas.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

Watershed Resources

An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This study documents some of these available resources for the Brooks Creek Watershed. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Watershed Coordinator

The Indiana Department of Environmental Management (IDEM) and the USDA cosponsor three regional watershed conservationist positions. The watershed conservationist is an advocate for watershed-level work in the region. Watershed conservationists can help direct actions of groups and stakeholders who are interested in working together to address problems in their watershed. They can help with everything from structuring public meetings to assisting with the compilation of a Watershed Management Plan. Their wealth of knowledge includes ideas about how to work with and respect all stakeholders in order to find the best plan for natural resource conservation within your watershed. Matt Jarvis is the regional watershed conservationist for the northern third of Indiana and has an office in the NRCS office in Delphi, Indiana. His contact information is found below.

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Natural Resources Conservation Service
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Coordinated Resource Management

The Coordinated Resource Management (CRM) process is an organized approach to identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal is an effective Watershed Management Plan through the establishment of common goals and actions to achieve those goals. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives guidance on how to plan with people to maximize benefits to the greatest number of people while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including the Blackford County SWCD) have loaner equipment that can be borrowed. Groups in Jay and Blackford Counties actively participate in the Riverwatch Program. Table 50 contains information about groups that have conducted volunteer monitoring in the two counties. Because neither Brooks Creek nor any of its tributaries have been monitored through the Hoosier Riverwatch Program, more participation should be advocated within the study watershed especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

TABLE 50. Groups that have participated in the Hoosier Riverwatch volunteer monitoring program in Jay and Blackford Counties.

County	Organization	City
Blackford	Blackford County SWCD	Hartford City
Jay	Judge Haynes Elementary	Portland
Jay	Jay County High School	Portland

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. Although no streams in the study watershed have been monitored by Hoosier Riverwatch participants, both the Judge Haynes Elementary School and the Jay County High School have participated in the program. The two schools are located in Portland and are close to the Brooks Creek Watershed. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline trends with which to compare future samples.

Other Local Groups

Other local groups also may offer resources and/or assistance for accomplishing watershed goals. Many local utilities, like electric and gas companies, offer grants for educational and environmental purposes. Additionally, large corporations give challenge grants for watershed projects. For more information on private grant foundations visit the web site http://www.fdncenter.org.

LITERATURE CITED

Allen, J. David. 1995. Stream Ecology: structure and function of running waters. Chapman and Hall, London.

APHA et al. 1995. Standard Methods for the Examination of Water and Wastewater, 19th edition. American Public Health Association, Washington, D.C.

Arora, K., S.K. Mickelson, J.L. Baker, D.P. Tierney, and C.J. Peters. 1993. Herbicide retention by vegetative buffer strips from runoff under natural rainfall. Trans. ASAE 39: 2155-2162.

Barbour et al. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. 2nd Edition. USEPA, Office of Water. Washington, D.C. EPA 841-B99-002.

Bowman, M.F. and R.C. Bailey. 1997. Does taxonomic resolution affect the multivariate description of the structure of freshwater benthic macroinvertebrate communities? Canadian Journal of Fisheries and Aquatic Sciences. 54:1802-1807.

Braun, E.R. 1980. A Fisheries Investigation of the Salamonie River in Huntington, Wells, Blackford, and Jay Counties, Indiana. Indiana Department of Natural Resources, Indianapolis, Indiana.

Braun, E.R. 1995. A Survey of the Fishes of the Little Wabash River in Huntington County, 1994. Indiana Department of Natural Resources, Indianapolis, Indiana.

Cogger, C.G. 1989. Septic System Waste Treatment in Soils. Washington State University Cooperative Extension Department. EB1475.

Conservation Technology Information Center. No date. Conservation Buffer Facts. [web page] http://www.ctic.purdue.edu/core4/buffer/bufferfact.html [Accessed March 3, 2000].

Conservation Technology Information Center. No date. Benefits of High-Residue Farming. [web page] http://www.ctic.purdue.edu/Core4/CT/Checklist/Page3.html [Accessed February 9, 2001].

Correll, David L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. Journal of Environmental Quality. 27(2):261-266.

Daniels, R.B. and J.W. Gilliam. 1987. Sediment and chemical load reduction by grass and riparian buffers. Soil Sci. Soc. Am. J. 60: 246-251.

Department of Transportation. 1988. Geographic Information Systems (GIS) Coverage data for Indiana Main Roads.

Dillaha, T.A., R.B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Trans. ASAE 32: 513-519.

EPA. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1998. 1998 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-F-98-005. U.S. Environmental Protection Agency, Washington, D.C.

Evans, M.G., K.J. Eck, B. Gauck, J.M. Krejci, J.E. Lake, and E.A. Matzat. 2000. Conservation Tillage Update: Keeping Soil Covered and Water Clean in the New Millennium. Purdue University Agronomy Department, West Layfayette, Indiana. AGRY-00-02.

Ferraro, S.P. and F.A. Cole. 1995. Taxonomic level sufficient for assessing pollution impacts in Southern California Bight macrobenthos- revisited. Environmental Toxicology and Chemistry. 14:1021-1040.

Fleming, A.H. In prep. Water Resource Availability in the Maumee River Basin. Indiana Department of Natural Resources, Division of Water, Indianapolis, Indiana.

Furse et al. 1984. The influence of seasonal and taxonomic factors on the ordination and classification of running water sites in Great Britain and on the prediction of their macroinvertebrate communities. Freshwater Biology. 14:257-280.

Gerba, C.P. and J.S. McLeod. 1976. Effect of sediments on the survival of *Escherichia coli* in marine water. Applied Microbiology. 32: 114-120.

Gerking, S.D. 1945. Distribution of the Fishes of Indiana. In: Investigation of Indiana Lakes and Streams, Vol. 3(1), Indiana Department of Conservation, Indianapolis and Indiana University, Bloomington, 137 pp.

Grant, W. 1999. A Survey for Septic System Effects on Barbee Lake Chain, Indiana.

Hale, M.D. 1966. Lakes and streams. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 21-39.

Hayes, J.C., B.J. Barfield, and R.I. Barnhisel. 1984. Performance of grass filters under laboratory and field conditions. Trans. ASAE 27: 1321-1331.

Hilsenhoff, William L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society. 7(1):65-68.

Homoya, M.A., B.D. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Indiana Academy of Science. Vol. 94. Indiana Natural Heritage Program. Indiana Department of Natural Resources, Indianapolis, Indiana.

IDEM. 2000. Indiana Water Quality Report. Department of Environmental Management, Indianapolis, Indiana.

Indiana Department of Environmental Management. 1996. Scoring criteria for the family level macroinvertebrate Index of Biotic Integrity (mIBI). Biological Studies Section, Indianapolis.

Indiana University/Purdue University, Ft. Wayne. 1996. Characteristics of Fine Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems. Department of Continuing Education, Ft. Wayne, Indiana.

Isenhart, T.M., R.C. Schultz, and J.P. Colletti. 1997. Watershed Restoration and Agricultural practices in the Midwest: Bear Creek of Iowa. In: Williams, J.E., C.A. Wood, and M.P. Dombeck (eds.) Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland, p. 318-334.

Jones, D.D. and J.E. Yahner. 1994. Operating and Maintaining the Home Septic System. Purdue University Cooperative Extension Service. ID-142.

Jones, W. 1996. Indiana Lake Water Quality Update for 1989-1993. Indiana Department of Environmental Management. Clean Lakes Program. Indianapolis, Indiana.

Kluess, S.K. 1986. Soil Survey of Blackford and Jay Counties, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Klumpp, J., M. McIntosh, and E. Wilkerson. 2000. An overview of Upper Stephen's Creek, Monroe County, Indiana. School of Public and Environmental Affairs Stream Ecology Report, Indiana University, Bloomington.

Leeds, R., L.C. Brown, M.R. Sulc, and L. VanLieshout. 1993. Vegetative Filter Strips: Application, Installation and Maintenance. Extension Fact Sheet, The Ohio State University Extension, AEX-467.

Lockridge, E.D. and E.L. Jensen. 1982. Soil Survey of Huntington County, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Marchant, R.L. et al. 1995. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. Marine and Freshwater Research. 46:501-506.

Mickelson, S.K. and J.L. Baker. 1993. Buffer strips for controlling herbicide runoff losses. Paper no. 932084. Am. Soc. Agric. Eng., St. Joseph, Michigan.

National Climatic Data Center. 1976. Climatography of the United States. No.60.

National Conservation Buffer Council. 1999. Environmental Benefits of Buffers. [web page] http://www.buffercouncil.org/benefits.html [Accessed February 9, 2001].

National Research Council. 1993. Soil and Water Quality: Agenda for Agriculture. National Academy Press, Washington, D.C.

Natural Resources Conservation Service. 2000. Conservation Practice Standard for Filter Strips. Code 393.

Natural Resources Conservation Service. No date. Indiana Field Office Technical Guide – Section III Conservation Management Systems. [web page] Http://www.in.nrcs.usda.gov/PlanningandTechnology/fotg/section3/section.3html (Accessed August 16, 2001).

Neely, T. 1992. Soil Survey of Wells County, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Ohio EPA. 1999. Association between nutrients, habitat, and the aquatic biota in Ohio rivers and streams. Ohio EPA Technical Bulletin MAS/1999-1-1, Columbus.

Olem, H. and G. Flock, eds. 1990. Lake and reservoir restoration guidance manual. 2nd edition. EPA 440/4-90-006. Prepared by North American Lake Management Society for U.S. Environmental Protection Agency, Washington, DC.

Petty, R.O. and M.T. Jackson. 1966. Plant communities. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 264-296.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. US Environmental Protection Agency, Washington, DC, EPA/440/4-89/001.

Purdue Cooperative Extension Service. 2000. Indiana T by 2000 Watershed Soil Loss Transects Data Set. Ft. Wayne, Indiana.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus.

Rankin, E.T. 1995. Habitat indices in water resource quality assessment, in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-11. US Environmental Protection Agency, Washington, D.C.

Roth, N.E. 1994. Land use, riparian vegetation, and stream ecosystem integrity in an agricultural watershed. MS Thesis, The University of Michigan, 148 pp.

Schmitt, T.J., M.G. Dosskay, and K.D. Hoagland. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. Journal of Environmental Quality, 28(5):1479-1489.

Sherer, B.M., R.J. Miner, J.A. Moore, and J.C. Buckhorse. 1992. Indicator bacterial survival in stream sediments. Journal of Environmental Quality. 21: 591-595.

Standard Methods for the Examination of Water and Wastewater, 19th ed. 1995. Andrew D. Eaton, Lenore S. Clesceri, and Arnold E. Greenberg (eds.). American Public Health Association, Washington, D.C.

Steedman, R.J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in Southern Ontario. Can. J. Fish. Aquat. Sci., 45:492-501.

Stephenson, D.A., A.H. Flemming, and D.M. Mickelson. 1988. Glacial Deposits. In: Back, W. (ed.) Hydrogeology: Boulder, Colorado, Geological Society of America, The Geology of North America, v. O-2.

Thomas, J.A. 1996. Soil Characteristics of "Buttermilk Ridge" Wabash Moraine, Wells County Indiana. Notes for the IU/PU (Ft. Wayne) Soils Course: Characteristics of Fine-Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems.

Ulrich, H.P. 1966. Soils. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 57-90.

US Census of Agriculture. 1997. Indiana Farm Land Use History, Jay County, Indiana. http://www.nass.usda.gov/in/historic Assessed on March 22, 2001.

US Census of Agriculture. 2000. County Data for Indiana. http://www.info.aes.purdue.edu\agstat\nass.html Assessed on January 31, 2001.

USDA. 1997. The Conservation Reserve Program. Washington, D.C. PA-1603.

USFWS. 1971-1992. National Wetlands Inventory (NWI). Dates range from Feb. 1971 to Dec. 1992, Geographic Information Systems (GIS) coverage data for streams.

USGS. 2000. Multi-resolution Land Characterization (MRLC), National Land Cover Data (NLCD). Last updated 03-16-2000, Geographic Information Systems (GIS) coverages for land use land cover.

USGS. 1972. Zanesville 7.5-Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960a. Pennville 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960b. Blaine 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960c. Ridgeville 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science. 37:130-137.

Waite, I.R. et al. 2000. Comparing strengths of geographic and nongeographic classifications of stream benthic macroinvertebrates in the Mid-Atlantic Highlands, USA. J. N. Am. Benthol. Soc. 19(3):429-441.

Walker, R.D. 1978. Task Force on Agricultural Nonpoint Sources of Pollution Subcommittee on Soil Erosion and Sedimentation. Illinois Institute for Environmental Quality, 72 pp.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. Bethesda, Maryland, 251 pp.

Wayne, W.J. 1966. Ice and land: a review of the tertiary and Pleistocene history of Indiana. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 21-39.

West, T.D., G.C. Steinhardt, and T.J. Vyn. 1999. Tillage Research Annual Report 1999. Purdue University Agronomy Department, West Layfayette, Indiana.

White, G. Unpublished data. Safety and Chemical Testing Instructions. Indiana Department of Natural Resources. Indianapolis, Indiana.

APPENDICES

APPENDIX 1:

Detailed Land Use and Land Cover for the Twelve Brooks Creek Subwatersheds

APPENDIX 1. Detailed Land Use and Land Cover for the Twelve Brooks Creek Subwatersheds.

TABLE A-1.1 Bales Ditch and Crooked Creek Subwatersheds.

Land Cover	area (acres)	area (ha)	%
Water	0.26	0.10	0.0094
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	112.64	45.60	4.0944
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.26	0.10	0.0094
Pasture/Grassland	135.58	54.89	4.9283
Row Crop	2486.03	1006.49	90.3682
Woody Wetland	15.98	6.47	0.5809
Herb. Wetland	0.26	0.10	0.0094
TOTAL	**2751.0**	**1113.8**	**100%**

TABLE A-1.2 Mud Creek Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	2.87	1.16	0.0772
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	213.57	86.47	5.7442
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.00	0.00	0.0000
Pasture/Grassland	457.52	185.23	12.3054
Row Crop	3036.63	1229.40	81.6737
Woody Wetland	5.98	2.42	0.1608
Herb. Wetland	1.43	0.58	0.0386
TOTAL	**3718.00**	**1505.26**	**100%**

TABLE A-1.3 Brooks One Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	0.4883	0.197687	0.0183
Low Intensity Residential	0.0000	0	0.0000
High Intensity Residential	0.0000	0	0.0000
Commercial	0.0000	0	0.0000
Deciduous Forest	164.0644	66.422843	6.1493
Evergreen Forest	0.0000	0	0.0000
Mixed Deciduous/Evergreen Forest	0.0000	0	0.0000

Pasture/Grassland	270.0227	109.32093	10.1208
Row Crop	2026.8792	820.59887	75.9700
Woody Wetland	206.5454	83.621615	7.7416
Herb. Wetland	0.0000	0	0.0000
TOTAL	**2668.0000**	**1080.1619**	**100%**

TABLE A-1.4 Harris Creek Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	0.36	0.15	0.0222
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	109.05	44.15	6.6371
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.00	0.00	0.0000
Pasture/Grassland	182.60	73.93	11.1136
Row Crop	1330.97	538.85	81.0083
Woody Wetland	16.02	6.49	0.9751
Herb. Wetland	4.01	1.62	0.2438
TOTAL	**1643.00**	**665.18**	**100%**

TABLE A-1.5 Brooks Two Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	0.00	0.00	0.0000
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	107.05	43.34	6.5157
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.00	0.00	0.0000
Pasture/Grassland	134.05	54.27	8.1590
Row Crop	1351.66	547.23	82.2681
Woody Wetland	50.23	20.34	3.0572
Herb. Wetland	0.00	0.00	0.0000
TOTAL	**1643.00**	**665.18**	**100%**

TABLE A-1.6 Smith-Hartman Ditch Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	5.58	2.26	0.2554
Low Intensity Residential	0.23	0.09	0.0106
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000

Deciduous Forest	172.78	69.95	7.9076
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.47	0.19	0.0213
Pasture/Grassland	368.59	149.22	16.8689
Row Crop	1634.33	661.67	74.7978
Woody Wetland	2.09	0.85	0.0958
Herb. Wetland	0.93	0.38	0.0426
TOTAL	**2185.00**	**884.62**	**100%**

TABLE A-1.7 Phillips Run Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	0.46	0.19	0.0219
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	351.08	142.14	16.6703
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.00	0.00	0.0000
Pasture/Grassland	243.73	98.67	11.5730
Row Crop	1497.61	606.32	71.1114
Woody Wetland	12.90	5.22	0.6126
Herb. Wetland	0.23	0.09	0.0109
TOTAL	**2106.00**	**852.63**	**100%**

TABLE A-1.8 Stephens Run and Jeffs Run Subwatersheds.

Land Cover	area (acres)	area (ha)	%
Water	18.36	7.43	0.2574
Low Intensity Residential	1.12	0.45	0.0157
High Intensity Residential	0.67	0.27	0.0094
Commercial	0.67	0.27	0.0094
Deciduous Forest	902.04	365.20	12.6424
Evergreen Forest	0.67	0.27	0.0094
Mixed Deciduous/Evergreen Forest	1.34	0.54	0.0188
Pasture/Grassland	1073.13	434.46	15.0403
Row Crop	5070.93	2053.01	71.0712
Woody Wetland	65.17	26.38	0.9133
Herb. Wetland	0.90	0.36	0.0126
TOTAL	**7135.00**	**2888.66**	**100%**

TABLE A-1.9 Headwaters Subwatershed.

Land Cover	area (acres)	area (ha)	%
Water	15.86	6.42	0.6244

Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	277.29	112.26	10.9171
Evergreen Forest	4.21	1.71	0.1659
Mixed Deciduous/Evergreen Forest	0.25	0.10	0.0098
Pasture/Grassland	374.93	151.79	14.7610
Row Crop	1848.38	748.33	72.7707
Woody Wetland	19.08	7.73	0.7512
Herb. Wetland	0.00	0.00	0.0000
TOTAL	**2540.00**	**1028.34**	**100%**

TABLE A-1.10 Mouth Subwatershed.

Land Cover	**area (acres)**	**area (ha)**	**%**
Water	3.19	1.29	0.2586
Low Intensity Residential	0.00	0.00	0.0000
High Intensity Residential	0.00	0.00	0.0000
Commercial	0.00	0.00	0.0000
Deciduous Forest	85.81	34.74	6.9540
Evergreen Forest	0.00	0.00	0.0000
Mixed Deciduous/Evergreen Forest	0.00	0.00	0.0000
Pasture/Grassland	71.98	29.14	5.8333
Row Crop	961.31	389.20	77.9023
Woody Wetland	111.70	45.22	9.0517
Herb. Wetland	0.00	0.00	0.0000
TOTAL	**1234.00**	**499.60**	**100%**

APPENDIX 2:

Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)

These photos are not included in the electronic version of this report.

APPENDIX 3:

Endangered, Threatened, and Rare Species List,
Brooks Creek Watershed

ENDANGERED, THREATENED, AND RARE SPECIES
AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM
THE BROOKS CREEK WATERSHED, INDIANA

Type.........	Element Name................	Common Name..............	State	Fed..	Townrang Sec...............		Date	Comments
PENNVILLE QUADRANGLE								
Bird	NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	024N012E	PENNVILLE	1931	
Insect	MACROMIA WABASHENSIS	WABASH BELTED SKIMMER DRAGONFLY	**	**	024N012E 34	NWQ SEQ	1994	
PETROLEUM QUADRANGLE								
High Quality Community	FOREST - FLATWOODS CENTRAL TILL PLAIN	CENTRAL TILL PLAIN FLATWOODS	SG	**	024N012E 30	WH EH & NEQ SWQ.	1984	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant, SRE=state reintroduced

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 4:

**Endangered, Threatened, and Rare Species List,
Blackford and Jay Counties**

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM BLACKFORD COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
COELOGLOSSUM VIRIDE VAR VIRESCENS	LONG-BRACT GREEN ORCHIS	ST	**	S2	G5T5
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
REPTILES					
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
MAMMALS					
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLATWOODS CENTRAL TILL PLAIN	CENTRAL TILL PLAIN FLATWOODS	SG	**	S2	G3
FOREST - FLOODPLAIN WET-MESIC	WET-MESIC FLOODPLAIN FOREST	SG	**	S3	G3?
WETLAND - MARSH	MARSH	SG	**	S4	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM JAY COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
ARTHROPODA: INSECTA: ODONATA (DRAGONFLIES; DAMSELFLIES)					
MACROMIA WABASHENSIS	WABASH BELTED SKIMMER DRAGONFLY	**	**	S1	G1G3Q
AMPHIBIANS					
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	S3	G5
BIRDS					
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
TYTO ALBA	BARN OWL	SE	**	S2	G5
MAMMALS					
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLATWOODS CENTRAL TILL PLAIN	CENTRAL TILL PLAIN FLATWOODS	SG	**	S2	G3
FOREST - FLOODPLAIN MESIC	MESIC FLOODPLAIN FOREST	SG	**	S1	G3?

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 5:

Stream Sampling Laboratory Datasheets

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40166
SAMPLE ID: SITE 1

DATE SAMPLED: 6/6/00 1:05
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 1

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.61	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	8.1		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	54	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	7.50	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	9.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	53	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	2400	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 99200 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40167
SAMPLE ID: SITE 2

DATE SAMPLED: 6/6/00 12:35
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 2

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.63	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.9		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	38	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.10	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	6.70	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	50	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	6600	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 91600 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40168
SAMPLE ID: SITE 3

DATE SAMPLED: 6/6/00 12:00
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 3

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.51	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.9		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	44	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.14	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	7.90	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	61	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	2600	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 108400 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40169
SAMPLE ID: SITE 4

DATE SAMPLED: 6/6/00 12:15
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 4

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.69	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	8.3		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	57	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	8.00	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	48	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	2200	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 53600 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40170
SAMPLE ID: SITE 5

DATE SAMPLED: 6/6/00 11:37
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 5

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.52	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.7		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	50	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.15	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	11.20	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	0.40	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	0.12	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	60	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	1400	col/100ml		JAS	6/7/00	SM(18th)-9222D

The Total Coliform Count = 65200 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40171
SAMPLE ID: SITE 6

DATE SAMPLED: 6/6/00 11:20
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 6

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.60	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.9		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	35	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.11	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	8.30	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	3.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	0.30	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	47	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	2600	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 82000 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

LAB NUMBER: 40172
SAMPLE ID: SITE 7

REPORT OF ANALYSIS

DATE SAMPLED: 6/6/00 11:05
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 7

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.57	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	8.0		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	50	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.26	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	11.20	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	0.35	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	0.18	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	57	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	2800	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

The Total Coliform Count = 63600 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40173
SAMPLE ID: SITE 8

DATE SAMPLED: 6/6/00 10:35
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 8

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.52	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	8.0		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	56	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	12.00	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	78	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	6200	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 56000 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.
3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40174
SAMPLE ID: SITE 9

DATE SAMPLED: 6/6/00 10:15
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 9

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.55	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.9		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	34	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	5.90	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	1.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	34	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	4000	col/100ml		JAS	6/7/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 70400 col/100 mL.

A&L

A & L GREAT LAKES LABORATORIES, INC.
3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40175
SAMPLE ID: SITE 10

DATE SAMPLED: 6/6/00 9:50 AM
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 10

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.59	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.9		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	12	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	3.90	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	2.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	11	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	1000	col/100ml		JAS	6/7/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 17800 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40176
SAMPLE ID: REF. 1

DATE SAMPLED: 6/6/00 2:45 PM
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 11

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.44	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.7		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	208	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	18.70	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	3.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	133	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	4800	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 74400 col/100 mL.

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40176
SAMPLE ID: REF. 1

DATE SAMPLED: 6/6/00 2:45 PM
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 11

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.44	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.7		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	208	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	18.70	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	3.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	133	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	4800	col/100ml		JAS	6/7/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 74400 col/100 mL.

A & L GREAT LAKES LABORATORIES, INC.
CHAIN OF CUSTODY DOCUMENTATION

Report To: Marianne Giolitto
J. F New + Assoc., Inc
708 Roosevelt Road
Walkerton, IN 46574

Project Reference:

Shipper/Waybill Number:

Sample Identification	Container Number	Container Type: Glass	Container Type: Plastic	Date Sampled	Time Sampled	Type Sample: Grab	Type Sample: Composite	Sample Preservation: Cool 4°C	Frozen	H_2SO_4 pH<2	HNO_3 pH<2	HCl pH<2	NaOH pH>12	.008% $Na_2S_2O_3$	Ascorbic Acid	Requested Analyses
Site 1				6/6/00 6/6/00 6/6/00	1:05 ↓											pH, nitrate + nitrite, TKN, ammonia-N, total phos., dissolved P, turbidity, total sus. solids, conductivity, fecal coliform
Site 2				↓	12:35 ↓											↓
Site 3				↓	12:00 ↓											↓
Site 4				↓	12:15 ↓											↓
Site 5				↓	11:37 ↓											↓
site 6				↓	11:20 ↓											↓

Sampled by: Marianne Giolitto (Signature)
Marianne Giolitto (Printed Name)

Relinquished by: Marianne Giolitto (Signature)
Marianne Giolitto (Printed Name)
Date: 6/6/00
Time: 3:54

Received by: Keith Henley (Signature)
Keith Henley (Printed Name)
Date: 6/6/2000
Time: 3:54

Special Instructions:

A & L GREAT LAKES LABORATORIES, INC.

CHAIN OF CUSTODY DOCUMENTATION

Report To: JF New - Marianne Giolotto
708 Roosevelt Rd.
Walkerton, IN 46574

Project Reference:

Shipper/Waybill Number:

Requested Analyses: pH, Nitrate, Nitrite, TKN, Ammonia-N, T.P., Dissolved P (ortho), Turbidity, TSS, conductivity, fecal coliform (ecoli)

Sample Identification	Container Number	Container Type: Glass	Container Type: Plastic	Date Sampled	Time Sampled	Type Sample: Grab	Type Sample: Composite	Sample Preservation: Cool 4C	Frozen	H_2SO_4 pH<2	HNO_3 pH<2	HCl pH<2	NaOH pH>12	.008% $Na_2S_2O_3$	Ascorbic Acid		Requested Analyses
site 7				6/6/00	11:05am												
				6/6/00	↓												
				6/6/00													
Site 8				6/6/00	10:35am												
				6/6/00	↓												
				6/6/00													
site 9				6/6/00	10:15am												
				6/6/00	↓												
				6/6/00													
site 10				6/6/00	9:50am												
				6/6/00	↓												
				6/6/00													
Ref. 1				6/6/00	2:45pm												
~~[illegible]~~				6/6/00	↓												
				6/6/00													

Sampled by: Jason Thron, Marianne Giolotto (Signature)
JT MG (Printed Name)

Relinquished by: Marianne Giolotto (Signature)
Jason Thron (Printed Name)
Date: 6/6/00
Time: 3:54

Received by: Keith Hanley (Signature)
Keith Hanley (Printed Name)
Date: 6/6/2000
Time: 3:54

Special Instructions:

APPENDIX 6:

QHEI Datasheet

STREAM: ______________________ RIVER MILE ______________ DATE: ____________________ QHEI SCORE [ ]

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE [ ]

TYPE	POOL	RIFFLE	TYPE	POOL	RIFFLE
BLDER/SLAB(10)	___	___	GRAVEL(7)	___	___
BOULDER(9)	___	___	SAND(6)	___	___
COBBLE(8)	___	___	BEDROCK(5)	___	___
HARDPAN(4)	___	___	DETRITUS(3)	___	___
MUCK/SILT(2)	___	___	ARTIFIC(0)	___	___

SUBSTRATE ORIGIN (all)
- LIMESTONE(1)
- RIP/RAP(0)
- TILLS(1)
- HARDPAN(0)
- SANDSTONE(0)
- SHALE(-1)
- COAL FINES(-2)

SILT COVER (one)
- SILT-HEAVY(-2)
- SILT-MOD(-1)
- SILT-NORM(0)
- SILT-FREE(1)

Extent of Embeddedness (check one)
- EXTENSIVE(-2)
- MODERATE(-1)
- LOW(0)
- NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [ ] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: ____

2) INSTREAM COVER:

COVER SCORE [ ]

TYPE (Check all that apply)
- UNDERCUT BANKS(1)
- OVERHANGING VEGETATION(1)
- SHALLOWS (IN SLOW WATER)(1)
- DEEP POOLS(2)
- ROOTWADS(1)
- BOULDERS(1)
- OXBOWS(1)
- AQUATIC MACROPHYTES(1)
- LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- EXTENSIVE >75%(11)
- MODERATE 25-75%(7)
- SPARSE 5-25%(3)
- NEARLY ABSENT <5%(1)

COMMENTS: ____

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE [ ]

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
HIGH(4)	EXCELLENT(7)	NONE(6)	HIGH(3)
MODERATE(3)	GOOD(5)	RECOVERED(4)	MODERATE(2)
LOW(2)	FAIR(3)	RECOVERING(3)	LOW(1)
NONE(1)	POOR(1)	RECENT OR NO RECOVERY(1)	

MODIFICATION/OTHER
- SNAGGING
- IMPOUND
- RELOCATION
- ISLAND
- CANOPY REMOVAL
- LEVEED
- DREDGING
- BANK SHAPING
- ONE SIDE CHANNEL MODIFICATION

COMMENTS: ____

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

River Right Looking Downstream

RIPARIAN SCORE [ ]

RIPARIAN WIDTH (per bank) — L R (per bank)
- WIDE >150 ft.(4)
- MODERATE 30-150 ft.(3)
- NARROW 15-30 ft.(2)
- VERY NARROW 3-15 ft.(1)
- NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY — L R (most predominant per bank)
- FOREST, SWAMP(3)
- OPEN PASTURE/ROW CROP(0)
- RESID.,PARK,NEW FIELD(1)
- FENCED PASTURE(1)

L R (per bank)
- URBAN OR INDUSTRIAL(0)
- SHRUB OR OLD FIELD(2)
- CONSERV. TILLAGE(1)
- MINING/CONSTRUCTION(0)

BANK EROSION — L R (per bank)
- NONE OR LITTLE(3)
- MODERATE(2)
- HEAVY OR SEVERE(1)

COMMENTS: ____

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0

POOL SCORE [ ]

MAX.DEPTH (Check 1)
- >4 ft.(6)
- 2.4-4 ft.(4)
- 1.2-2.4 ft.(2)
- <1.2 ft.(1)
- <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- POOL WIDTH>RIFFLE WIDTH(2)
- POOL WIDTH=RIFFLE WIDTH(1)
- POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- TORRENTIAL(-1)
- EDDIES(1)
- FAST(1)
- INTERSTITIAL(-1)
- MODERATE(1)
- INTERMITTENT(-2)
- SLOW(1)

COMMENTS: ____

RIFFLE SCORE [ ]

RIFFLE/RUN DEPTH
- GENERALLY >4 in. MAX.>20 in.(4)
- GENERALLY >4 in. MAX.<20 in.(3)
- GENERALLY 2-4 in.(1)
- GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- STABLE (e.g., Cobble,Boulder)(2)
- MOD.STABLE (e.g., Pea Gravel)(1)
- UNSTABLE (Gravel, Sand)(0)
- NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- EXTENSIVE(-1)
- NONE(2)
- MODERATE(0)
- NO RIFFLE(0)
- LOW(1)

COMMENTS: ____

6) GRADIENT (FEET/MILE): _____ % POOL _____ % RIFFLE _____ % RUN _____ GRADIENT SCORE [ ]

APPENDIX 7:

Detailed mIBI Results

APPENDIX 7. Detailed mIBI Results.

Reference Site:

TABLE A-7.1 Reference Site multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Dytiscidae	3			0	4.84
Coleoptera	Noteridae	3			0	4.84
Diptera	Chironomidae	22		8	176	**35.48**
Diptera	Ephydridae	3		6	18	4.84
Diptera	Stratiomyidae	1			0	1.61
Ephemeroptera	Ephemerellidae	1	1	1	1	1.61
Ephemeroptera	Heptageniidae	15	15	4	60	24.19
Hemiptera	Gerridae	1			0	1.61
Hemiptera	Hebridae	10			0	16.13
Trichoptera	Polycentropodidae	1	1	6	6	1.61
Trichoptera	Psychomyiidae	2		2	4	3.23
		62	**17**		**6.023 HBI**	

TABLE A-7.2 Reference Site mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	6.02	0
No. Taxa (family)	11	4
% Dominant Taxa	35.5%	4
EPT Index	3	2
EPT Count/Total Count	0.27	2
EPT Abun./Chir. Abun.	0.77	0
mIBI Score		**2.0**

Site 1. Brooks Creek:

TABLE A-7.3 Site 1 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Elmidae	4		4	16	4.04
Coleoptera	Hydrophilidae	1			0	1.01
Diptera	Chironomidae	5		8	40	5.05
Ephemeroptera	Baetidae	4	4	4	16	4.04
Ephemeroptera	Heptageniidae	24	24	4	96	24.24
Gastropoda	Physidae	1			0	1.01
Megaloptera	Sialidae	5		4	20	5.05
Odonata	Coenagrionidae	1		9	9	1.01
Odonata	Gomphidae	2		1	2	2.02
Trichoptera	Hydropsychidae	52	52	4	208	**52.53**
		99	**80**		**4.20 HBI**	

TABLE A-7.4 Site 1 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.20	6
No. Taxa (family)	10	2
% Dominant Taxa	52.5%	2
EPT Index	3	2
EPT Count/Total Count	0.81	8
EPT Abun./Chir. Abun.	16.00	8
mIBI Score		**4.7**

Site 2. Mud Creek:

TABLE A-7.5 Site 2 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Amphipoda	Gammaridae	1		4	4	0.92
Coleoptera	Haliplidae	5			0	4.59
Coleoptera	Hydrophilidae	1			0	0.92
Diptera	Chironimidae	3		8	24	2.75
Diptera	Stratiomyidae	1			0	0.92
Diptera	Tabanidae	2		6	12	1.83
Ephemeroptera	Baetidae	1	1	4	4	0.92
Ephemeroptera	Baetiscidae	5	5	3	15	4.59
Ephemeroptera	Heptageniidae	19	19	4	76	17.43
Gastropoda	Ancylidae	1			0	0.92
Gastropoda	Physidae	43			0	**39.45**
Hemiptera	Mesoveliidae	1			0	0.92
Isopoda	Asellidae	1		8	8	0.92
Megaloptera	Sialidae	2		4	8	1.83
Odonata	Gomphidae	12		1	12	11.01
Trichoptera	Hydropsychidae	11	11	4	44	10.09
		109	**36**		**3.63 HBI**	

TABLE A-7.6 Site 2 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	3.63	8
No. Taxa (family)	16	6
% Dominant Taxa	39.4%	4
EPT Index	4	4
EPT Count/Total Count	0.33	4
EPT Abun./Chir. Abun.	12.00	8
mIBI Score		**5.7**

Site 3. Mud Creek:

TABLE A-7.7 Site 3 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Amphipoda	Talitridae	2			0	2.02
Bivalia	Sphaeriidae	1			0	1.01
Coleoptera	Dytiscidae	2			0	2.02
Coleoptera	Elmidae	10		4	40	10.10
Diptera	Culicidae	2			0	2.02
Ephemeroptera	Baetidae	4	4	4	16	4.04
Ephemeroptera	Ephemeridae	1	1	4	4	1.01
Ephemeroptera	Heptageniidae	4	4	4	16	4.04
Gastropoda	Ancylidae	1			0	1.01
Gastropoda	Physidae	18			0	18.18
Odonata	Aeshnidae	1		3	3	1.01
Odonata	Coenagrionidae	3		9	27	3.03
Odonata	Gomphidae	1		1	1	1.01
Odonata	Libellulidae	3		9	27	3.03
Trichoptera	Hydropsychidae	46	46	4	184	**46.46**
		99	**55**		**4.36 HBI**	

TABLE A-7.8 Site 3 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.36	6
No. Taxa (family)	15	6
% Dominant Taxa	46.5%	4
EPT Index	4	4
EPT Count/Total Count	0.56	6
EPT Abun./Chir. Abun.		8
mIBI Score		**5.7**

Site 4. Brooks Creek:

TABLE A-7.9 Site 4 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Hydrophilidae	1			0	1.01
Diptera	Chironomidae	74		8	592	**74.75**
Ephemeroptera	Heptageniidae	1	1	4	4	1.01
Ephemeroptera	Neoephemeridae	1	1		0	1.01
Gastropoda	Physidae	9			0	9.09
Hemiptera	Gerridae	1			0	1.01
Hemiptera	Mesovellidae	1			0	1.01
Hemiptera	Veliidae	1			0	1.01
Odonata	Libellulidae	1		9	9	1.01
Trichoptera	Hydropsychidae	9	9	4	36	9.09
		99	**11**		**7.54 HBI**	

TABLE A-7.10 Site 4 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	7.54	0
No. Taxa (family)	10	2
% Dominant Taxa	74.7%	0
EPT Index	3	2
EPT Count/Total Count	0.11	0
EPT Abun./Chir. Abun.	0.15	0
mIBI Score		**0.7**

Site 5. Harris Creek:

TABLE A-7.11 Site 5 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Elmidae	14		4	56	13.21
Diptera	Simuliidae	6		6	36	5.66
Ephemeroptera	Heptageniidae	8	8	4	32	7.55
Gastropoda	Physidae	43			0	**40.57**
Gastropoda	Planorbidae	27			0	25.47
Plecoptera	Perlidae	1	1	1	1	0.94
Trichoptera	Hydropsychidae	7	7	4	28	6.60
		106	**16**		**4.250 HBI**	

TABLE A-7.12 Site 5 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.25	6
No. Taxa (family)	7	0
% Dominant Taxa	40.6%	4
EPT Index	3	2
EPT Count/Total Count	0.15	2
EPT Abun./Chir. Abun.		8
mIBI Score		**3.7**

Site 6. Brooks Creek:

TABLE A-7.13 Site 6 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Elmidae	5		4	20	4.39
Coleoptera	Dytiscidae	2			0	1.75
Diptera	Chironomidae	9		8	72	7.89
Diptera	Culicidae	2			0	1.75
Diptera	Simuliidae	10		6	60	8.77
Diptera	Tipulidae	1		3	3	0.88
Ephemeroptera	Baetidae	12	12	4	48	10.53
Gastropoda	Physidae	6			0	5.26
Odonata	Coenagrionidae	2		9	18	1.75
Odonata	Libellulidae	3		9	0	2.63
Trichoptera	Hydropsychidae	62	62	4	248	**54.39**
		114	**74**		**4.510 HBI**	

TABLE A-7.14 Site 6 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.51	6
No. Taxa (family)	11	4
% Dominant Taxa	54.4%	2
EPT Index	2	0
EPT Count/Total Count	0.65	6
EPT Abun./Chir. Abun.	8.22	6
mIBI Score		**4.0**

Site 7. Hartman Ditch:

TABLE A-7.15 Site 7 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Bivalvia	Sphaeridae	1			0	33.33
Bivalvia		1				33.33
Coleoptera	Curculionidae	1			0	33.33
		3	**0**		**0.000 HBI**	

TABLE A-7.16 Site 7 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI		
No. Taxa (family)	3	0
% Dominant Taxa		
EPT Index		
EPT Count/Total Count		
EPT Abun./Chir. Abun.		
mIBI Score		**0.0**

Site 8. Phillips Run:

TABLE A-7.17 Site 8 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Coleoptera	Elmidae	2		4	8	4.35
Ephemeroptera	Ephemereliidae	1	1	1	1	2.17
Ephemeroptera	Heptageniidae	13	13	4	52	**28.26**
Gastropoda	Physidae	4			0	8.70
Hemiptera	Gerridae	12			0	26.09
Isopoda	Asellidae	3		8	24	6.52
Trichoptera	Hydropsychidae	11	11	4	44	23.91
		46	**25**		**4.300 HBI**	

TABLE A-7.18 Site 8 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.30	6
No. Taxa (family)	7	0
% Dominant Taxa	28.3%	6
EPT Index	3	2
EPT Count/Total Count	0.54	6
EPT Abun./Chir. Abun.		8
mIBI Score		**4.7**

Site 9. Brooks Creek:

TABLE A-7.19 Site 9 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Bivalvia	Sphaeridae	2			0	2.04
Coleoptera	Dryopidae	1		5	5	1.02
Coleoptera	Dytiscidae	2			0	2.04
Coleoptera	Elmidae	12		4	48	12.24
Coleoptera	Gyrinidae	4			0	4.08
Coleoptera	Haliplidae	1			0	1.02
Coleoptera	Hydrophilidae	4			0	4.08
Diptera	Brachycera	10			0	10.20
Diptera	Chironomidae	8		8	64	8.16
Diptera	Culicidae	2			0	2.04
Ephemeroptera	Baetidae	10	10	4	40	10.20
Ephemeroptera	Heptageniidae	4	4	4	16	4.08
Ephemeroptera	Tricorythidae	1	1	4	4	1.02
Gastropoda	Physidae	13			0	13.27
Gastropoda	Planorbidae	2			0	2.04
Odonata	Aeshniidae	6		9	0	6.12
Odonata	Libellulidae	1		3	0	1.02
Trichoptera	Hydropsychidae	15	15	4	60	**15.31**
		98	**30**		**3.823 HBI**	

TABLE A-7.20 Site 9 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	3.82	6
No. Taxa (family)	18	0
% Dominant Taxa	15.3%	6
EPT Index	4	2
EPT Count/Total Count	0.31	6
EPT Abun./Chir. Abun.	3.75	8
mIBI Score		**4.7**

Site 10. Brooks Creek:

TABLE A-7.21 Site 10 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# • t	%
Amphipoda	Talitridae	4		8	32	4.12
Coleoptera	Curculionidae	1			0	1.03
Coleoptera	Dytiscidae	3			0	3.09
Coleoptera	Elmidae	11		4	44	11.34
Coleoptera	Gyrinidae	1			0	1.03
Diptera	Chironomidae	3		8	24	3.09
Diptera	Ephydridae	3		6	18	3.09
Diptera	Simuliidae	1		6	0	1.03
Diptera	Stratiomyidae	1			0	1.03
Diptera	Tipulidae	12		3	36	12.37
Ephemeroptera	Ephemeridae	4	4	4	16	4.12
Ephemeroptera	Heptageniidae	6	6	4	24	6.19
Ephemeroptera	Neoephemeridae	2	2		0	2.06
Gastropoda	Physidae	4			0	4.12
Gastropoda	Planorbidae	21			0	**21.65**
Hemiptera	Gerridae	1			0	1.03
Hemiptera	Hebridae	1			0	1.03
Isopoda	Asellidae	2		8	0	2.06
Lepidoptera	Pyralidae	3		5	0	3.09
Megaloptera	Sialidae	1		4	0	1.03
Odonata	Coenagrionidae	2		9	0	2.06
Trichoptera	Hydropsychidae	9	9	4	0	9.28
Trichoptera	Hydroptilidae	1	1	4	4	1.03
		97	**22**		**3.194 HBI**	

TABLE A-7.22 Site 10 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	3.19	8
No. Taxa (family)	23	8
% Dominant Taxa	21.6%	8
EPT Index	5	4
EPT Count/Total Count	0.23	2
EPT Abun./Chir. Abun.	7.33	6
mIBI Score		**6.0**